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The Nature of Science in physics teaching in Italy

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Summary. — In this paper, we describe two studies carried out in the research field of Nature of Science (NOS). The general aim was to explore the role of NOS in the Italian physics teaching context. In both studies, the Reconceptualized Family Resemblance Approach to NOS (RFN) was adopted as the theoretical framework. In the first study, the RFN was used to investigate the presence of NOS at an institutional level, and physics guidelines for the Italian Scientific Lyceum were analysed. Then, an Epistemic Network Analysis allowed us to visualise the connections between the elements of the nature of physics that emerged in various sections of the guidelines. In the second study, one element of NOS, scientific practices, was explored from the perspective of physics teachers. We investigated how physics practices, such as modelling and experimenting, were taught in class by a sample of very motivated teachers.

1. – Aims and structure of the work

This work is positioned in the research field of Science Education that deals with the Nature of Science (NOS). NOS addresses important questions like "what is science?", and "which aspects of science should be taught at school?" [1]. This study focused on one scientific discipline, physics, and the general aim was to explore components of NOS in the Italian physics teaching context. NOS teaching has been recognised as beneficial for several reasons, such as enabling students to understand the process of science, make informed decisions on socio-scientific issues, appreciate the value of science as part of contemporary culture, be more aware of the norms of the scientific community, and better master science contents [2]. Looking at the Italian physics high school context, NOS teaching is not explicitly included in the official school guidelines [3, 4]. Thus, the first goal of this study was to investigate if NOS elements were implicitly included in physics guidelines. Italian school guidelines are meant to be non-prescriptive by nature. They intend to give suggestions and hints, to orient teachers towards contents and attitudes that are considered crucial for disciplinary teaching. Therefore, to understand how NOS is taught at school, also experiences of single teachers may provide important examples. The second aim of this study was to investigate how NOS elements are practically taught at high schools and which role they play in learning physics.

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The article is structured in three parts: a brief introduction to the Reconceptualized Family Resemblance Approach to NOS (RFN), which has been used as the theoretical model of study (sect. **2**); a summary of the first study, in which RFN was applied to the official physics guidelines analysis (sect. **3**); a summing-up of the second study, in which teaching of one RFN element in physics was investigated (sect. **4**). It is worth saying that all the studies are explained in much detail in our master dissertation [5].

2. – Theoretical framework

In Science Education research, multiple perspectives on NOS exist (*e.g.*, Feature of Science, Consensus View). All these perspectives come from different epistemological traditions and views. We adopted the RFN, developed by Erduran and Dagher in 2014 [1].

RFN is grounded on Wittgenstein's perspective, representing science (and scientific disciplines such as physics) in all its complexity. The approach assumes that the nature of each scientific discipline is comprised of an intertwining of a cognitive-epistemic system of science, and a social-institutional system of science, that are continuously influenced by each other. Each system is made of categories that refer to different aspects of science. Categories of the cognitive-epistemic system are Aims and Values of science (AV), Scientific Practices (SP), Methods and Methodological Rules (MMR), Scientific Knowledge (SK). The second system comprises other seven categories, contributing to showing an authentic image of science, made by real people: Professional Activities (PA), Scientific Ethos (SE), Social Certification and Dissemination (SCD), Social Values of Science (SVS), Social Organisations and Interactions (SOI), Political Power Structures (PPS), and Financial Systems (FS).

This framework avoids the use of a list of features or a closed definition of science, depicting a holistic and comprehensive image of science [1]. Moreover, RFN is used for science curriculum analysis [6] and can also be used for physics curriculum analysis.

3. – First study: Italian physics guidelines analysis

3˙1. *Italian physics guidelines.* – For the analysis, I have used the guidelines of the Scientific Lyceum high school, because this type of school provides the longest and most articulated physics course among Italian upper secondary schools [4]. These guidelines are structured in a general section that displays an overview of all general objectives and skills to be achieved in the 5-year physics course, followed by a specific section, organised in three parts (grades 9-10/11-12/13), that illustrates all physics contents and themes of the course.

3˙2. *Design and method.* – The whole document was subdivided into 29 subsections. In each one, two analysts looked for all sentences or single words belonging to at least one NOS category of RFN. After a phase dedicated to checking data reliability, a final categorisation has been obtained. Considering two or more NOS categories as *connected* when they are found in the same subsection, an Epistemic Network Analysis (ENA) [7] has been carried out to show the connections between the NOS elements in each section of the guidelines (an example is given below in figs. 1(a) and (b)).

3˙3. *Results.* – The number of NOS categories that were found in the document is reported in table I. There was a consistent presence of cognitive-epistemic NOS categories in the whole document (46), in contrast with a scarce presence of categories belonging to

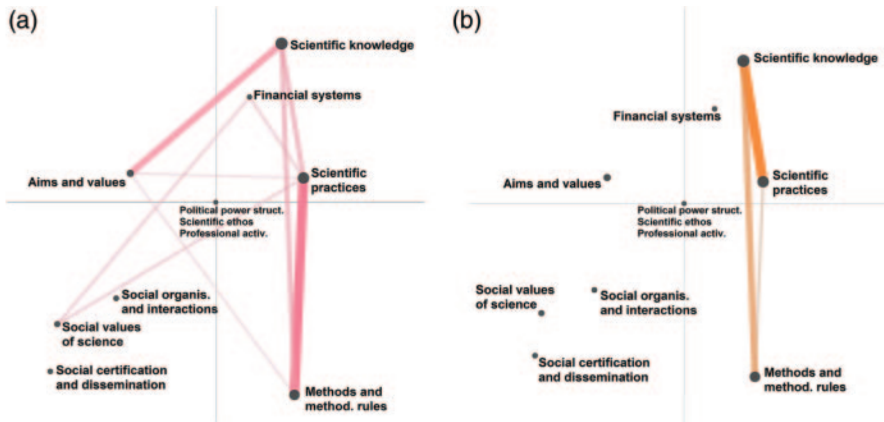

Fig. 1. – (a) Connections among NOS categories found in the general section. (b) Connections among NOS categories found in the specific section (grades 9-10).

the social-institutional system of science (6). The main element stressed by the authors of the guidelines is "scientific knowledge" (found in 22 subsections out of 29 total). Among cognitive-epistemic categories, there is a lack of "aims and values". An interesting result has been provided by the ENA that was used to visualise the links between the various NOS elements. The results show, from the general section of physics guidelines, a rich and varied structure of connections between many NOS categories (fig. 1(a)). On the contrary, the rich structure of connections with "aims and values" and social-institutional categories collapses in grades 9-10 of the specific section (fig. 1(b)) [4, 5].

4. – Second study: teachers interviews on Physics Practices teaching

4·1. *Purpose*. – For the second study, we investigated how scientific practices, like modeling, arguing, making predictions, and experimenting, are taught in physics lessons. According to RFN, SP are not meant as simple scientific activities, but as epistemic entities, that deeply contribute to the generation and evaluation of scientific knowledge.

4·2. *Sample and analytical method*. – To investigate how teachers implemented scientific practices in their teaching, an interview protocol was developed and tested [8]. Five highly motivated high school physics teachers were interviewed. They were in early or mid or end-career. Then, interview transcriptions were re-organised, performing a

Table I. – *Number of NOS categories found in the Italian physics guidelines.*

Guidelines	Cognit. - Epistem. c.				Social - Institutional categories						
Section	AV	SP	MMR	SK	PA	SE	SCD	SVS	SOI	PPS	FS
General/8	2	6	3	3	0	0	0	1	1	0	1
Specific/21	1	6	6	19	0	0	1	1	1	0	0
Total/29	3	12	9	22	0	0	1	2	2	0	1

thematic analysis, to group the teachers' contributions on different themes. Also, five teachers' schematic maps were created to display all the teachers' single contributions.

4·3. *Results.* – All teachers claimed to teach Physics Practices (PP) and make activities about them. Modeling, for example, is taught while addressing specific contents (*e.g.*, kinematics). Thus, teachers accompany students to comprehend the discipline, exploring it from the inside, helping them understand how physicists work. Textbooks are less used for PP teaching because they often do not explicit epistemic choices (*e.g.*, validity limits). The teachers' observations show that PP teaching is essential to make students achieve a coherent and rich understanding of physics, to value the epistemic dimension of discipline, and to recognize the meaning of knowledge. For students, PP may have enormous cultural and emotional value, like in the experimental practice in which they face errors and failures. In physics, these are not a mere source of frustration, but concrete opportunities, to improve experiments, reach scientific goals or at best discover something new.

5. – Conclusions

This work shows that many NOS cues are present in the Italian physics guidelines and NOS teaching is valuable and important for all interviewed physics teachers. Italian physics guidelines intentionally leave room to teachers for NOS implementation in the classrooms, but to make it relevant it seems necessary to involve teachers who have solid education, strong motivation, and are didactically independent.

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