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Introduction: The Application of the History and Philosophy of Science in Science Teaching

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For more than a century now, philosophers and historians of science, educators and science education researchers have been providing promising ideas and fruitful feedback about using the history and philosophy of science for a more meaningful science education. Often curriculum designers and educational policy makers listened, and attended to the advice coming from these HPST scholars, e.g.: after World War II, in order to re-humanise science; during the Cold War, to convince the general public that funding scientific research is crucial; in the dawn of the digital era, in order to justify the dependence of society on technology; and nowadays, in the times of scientific literacy, for promoting public understanding of science among consumers and workers in an era of globalisation.

But we could ask is anyone listening to the philosophers and historians of science, the educators and the science education researchers when they provide a variety of reasons on how and why the history and philosophy of science may become a dynamic transformation tool for science teaching? In most of the cases up till now, curricula designers and educational policy makers, adhering to their own political (and financial) theories, grasp from the colourful and penetrating HPST teaching approaches only those elements that support their agendas and help the realisation of their own educational policy.

Is it only their fault? Has the HPST community done anything to prevent this occasional and anecdotal use of the history and philosophy of science input in science teaching? We think there is need for concrete theoretical frameworks, applied case studies, research guidelines and results, as well as for a definition of future goals and perspectives in the field of the history and philosophy of science in science teaching. Many fruitful research ideas and teaching approaches have been developed and proposed over the decades, but they seem so scattered that they sometimes do not build upon each other, and in many cases they even appear as antagonistic, e.g., the point of view of historians of science clashing with the point of view of science education researchers. However, this situation

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can be justified as the HPST field is a junction of different study and research traditions: history of science, philosophy of science, and science education, but also sociology of science, cognitive psychology, developmental psychology, or more generally 'science studies'.

We think there is need for working in research groups formed from specialists coming from all the above areas with a commitment to make the ideas that each field supports compatible to the ideas coming from the other fields under the umbrella of HPST, keeping in mind the goal of transforming research ideas and teaching approaches into proposals of applicable, easy to comprehend and disseminate teaching scenarios and guidelines. Then there is great chance that HPST aims are not misinterpreted, misused or partly and selectively realised. Scholars from all related disciplines have to feel secure to open all their cards and work with each other; state and elaborate their disagreements, as this will bring HPST research forward; make their demands and expectations meet and also fulfill the current educational goals, or promote the development of new ones.

This is not an easy operation; it takes time and work. This special issue of *Science & Education* makes an effort to contribute in this direction: all the papers included in it reveal aspects of the problems and perspectives around the realisation of HPST approaches in science teaching.

The first group of papers deal with research on ways to integrate the meta-sciences (history and philosophy of science) in science education. There are a variety of issues concerning the active or latent theoretical frameworks and foundations underneath approaches to science teaching informed by the history and philosophy of science.

Teixeira, Greca and Freire present in their paper a meta-analysis of HPST case studies. They collected, categorised, analysed, and commented a variety of studies offering the "critical and reliable information" that is needed for science education researchers in order to understand and incorporate HPST elements contributing to science education research, with a special focus on those concerning NOS.

In Santilli's paper, through three case studies the understanding of science and technology interdependence and their interrelations to society is promoted. Although the paper refers to teachers and learners in a school of engineering, it offers insights for science-technology-society issues that concern science teaching in general, focusing on the teaching of NOS and the nature of technology. The paper elaborates the limits of independent evolution of knowledge in the context of a multi-factored environment. How autonomous is the development of science and technology when it takes place in society, with all the economical, cultural, ethical, utilitarian, political (and many other) implications?

Faria, Pereira and Chagas in their paper move along the same line of thought, presenting a palpable example of science-society interaction through the work of a prominent oceanographer. In their case, a science museum offers the learning environment for the development and the application of two workshops on classification and specimen drawing aiming at NOS understandings and motivation for science learning, and reinforcing the co-operation between science museums and schools in the context of the history and philosophy of science in science teaching.

The second set of papers elaborates on research around practical implementations of the meta-sciences in science education. No matter how inspired an HPST informed didactical proposal is, there is need for research data and results from its implementation in the classroom. There is room to learn both from what went well and from what went wrong. As we said, HPST comprises researchers from many fields of scholarly endeavour; their research traditions differ in many aspects. It is thus important to bring to the forefront some traits of science education research that are substantive to the advancement of the discipline: careful, comparative and critical observation; different kinds of measurements; data collection and interpretation; evaluation and assessment; production and refinement of theoretical models. Data supporting theoretical claims are valuable, but even more valuable are data that defy or contradict our initial hypotheses, because in the case of HPST they reveal the possibilities and limits of the interactions between the history and philosophy of science and science education, and furthermore spot areas for future research projects.

Arriassecq and Greca in their paper gather data in favour of the contribution of the use of the history and philosophy of science to conceptual and motivational aspects of science learning. The history and philosophy of science in this case offer the background for a contextualised teaching approach concerning special relativity theory in secondary education. In this paper, an example of productive co-ordination of history of science, epistemology and pedagogy is presented, focusing on the fact that, in HPST informed learning environments, students not only appreciate knowledge comprehension but are also inspired to be involved in learning science.

Develaki in her paper offers the perspective of HPST reinforcing classroom science teaching, adding on science textbooks (that usually lack of HPST and NOS information) and contributing in teacher training. In this case, Newton's theory of gravitation is the starting point for elaborating fundamental factors of the nature of science, such as creativity, theory evolution, model formation and scientific methods, whereas direct teaching of NOS aspects is incorporated into suitable science content.

In Peters' paper an interesting question is put forward: How to compare explicit and implicit nature of science teaching? The author attempts to provide data and evidence to link NOS knowledge and content knowledge. Recorded data point out that, when comparing the two teaching modes on different groups, the explicit group outperforms the implicit one in NOS understandings, in content knowledge assessment, in inquiry work, and in scientific argumentation skills. Peters with his research is showing that it is time for more brave and fundamental interventions where HPST and NOS aspects are not only decorative background teaching elements but structural core teaching aims.

Richards in his paper presents an example of the incorporation of the history and philosophy of science in science teaching using interactive demonstrations. Students get familiar with retrograde motion walking through the motions of the planets in both the Ptolemaic and the Copernican systems. Scientific argumentation is reinforced by body movements, and research data show that the students who participated in the implementation perform better on examination questions about the motion of planets.

Décamp and de Hosson's paper presents an analysis of the widely used instructional activity that uses Eratosthenes' method to measure the circumference of Earth; they want to examine to what extent it can be relevant to deal with issues related to the nature of science and its history. The authors revise the assumptions under the traditional versions of the activity, which appears not to be as straightforward for students as previously claimed. Instead, they propose an educational reconstruction of Eratosthenes' measurements based on a narrative by Cleomedes (first century AD). The paper presents the of notion of "approximation" as a key concept of NOS.

In the last paper, Braga, Guerra and Reis aim at evaluating the viability of using scientific controversies in teaching. They present an educational project introducing some "historico-philosophical clashes" into the classical secondary phyisics curriculum. The authors deal with the debate between the French nineteenth century physicists Biot and Ampère, referred to the diverse interpretations of Oersted's experiment.

The papers included in this special issue touch many of the research questions still open in the field of the use of the history and philosophy of science in science teaching: How to record, categorise and compare previous case studies? How to promote the understanding of science-technology-society interrelations? How to co-ordinate science museums and schools in science teaching? How to contextualise science teaching in order to promote NOS understandings? How to incorporate NOS aspects in science teaching in a way that does not create but rather solves problems for the teachers? How to compare explicit and implicit NOS teaching approaches? How to transform aspects of the history and philosophy of science into motivating and fruitful classroom activities?

The above are only some key questions that can be found in the papers, there are more issues therein, coming from current research concerning the history and philosophy of science in science teaching. Research questions need space to grow into research projects, and research data need space to flourish into actual curriculum and classroom implementations. The challenge is to shift from theoretical meta-analyses to HPST realisations in the classrooms, accompanied with the study of all contributing parameters and with the formation of a matrix of analysis that contributes to put together some of the different research and academic traditions of the disciplines converging into this exciting area.