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IDTC Dossier
Methods and Cognitive Modelling in the History and Philosophy of Science–&–Education

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Introduction

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In order to inquire into the foundations of the History and Philosophy of Science & its connection to Education, more specifically, teaching science-NoS, the *Inter-Divisional Teaching Commission* (IDTC)[3] reached high-level researchers to share their most recent works and findings in methods and cognitive modelling as the IDTC Special Issue on HPS-&-Education. By combining approaches of natural sciences & humanities in the investigation of the topics and promoting the cooperation between teaching educators, historians of science, historians and philosophers of science and specialist, the following articles offer an interesting influence on the actual debate from scientific, educationally and culturally standpoints.

In the context of nowadays constraints and technological progress regarding the teaching of physical and mathematical sciences, the investigation of the relevant scientific-educational questions is becoming more and more emergent. As such, and since science is synonymous with modernity and progress, research has to be evolving with its time as well as *Nature of Science*, *Scientific Mediation*, *Popularization of Science and Technique*, and *Teaching methods and contents*. Moreover, physics (Pisano 2009; Pisano and Capecchi 2015),

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[3] The Inter-Divisional Teaching Commission (IDTC) is an inter-commission of the Division of Logic, Methodology, and Philosophy of Science and Technology (DLMPST) and The Division of History of Science and Technology (DHST); as parts of the International Union of History and Philosophy of Science and Technology (IUHPST). The General Assembly of the DLMPS at its Nancy Congress (July 2011) agreed to an earlier DHST (IUHPST/DLMPST/DHST) resolution to establish an Inter-Divisional Teaching Commission (IDTC) and its officers. The Inter-divisional Teaching Commission wants to offer a website-platform to promote its activities, opening discussions, grants and news and publications relevant to the History and Philosophy of Science & Education. More detail here: https://www.idtc-iuhps.com

mathematics (Dhombres 1992) and science education (Pisano and Bussotti 2015a, 2015c) are also a complex social phenomenon (Pisano 2016) since they are influenced by the labour market and the elementary knowledge of sciences required by anyone in the social-economic daily life.

The newly found advances related to reflections on methods and modelling in teaching sciences, theoretical and practices as well as the historical, historiographical and philosophical analyses done and peer-reviewed will be explored in the following pages. Combining different disciplines, more general and broader questions about *Nature of Science* and *Teaching/Science Education* will also be discussed in their relationship through the scope of *Historical Epistemology of Science*, *Psychology*, *History of Science* and even *Computing Science*.

The importance of the *History of Science* methods and related cognitive processes for teaching (really scientifically) the sciences is an invaluable pedagogical tool – which could be reasonably better implemented both in the curricula and lectures. Of course, even if managing to completely merge Science–with–its–History or much better, into–the–History, a foundational scientific learning–teaching programme might naturally arise: i.e., a) reading primary sources, b) understating/justify conflicts among theories, modelling and results,[4] c) understanding the role played by technics, technologies and related types of machinery within a scientific apparatus, etc. On the contrary, a consequence is a sort of positivist and notionistic teaching sciences, worst if full of repetitive exercises. On the other hand, also by rehabilitating – critically – previous works and results, i.e., by the likes of Ernst Mach (1838–1916), Alexandre Koyré[5] (1892–1964), Jean William Fritz Piaget (1896–1980), Karl Raimund Popper (1902–1994) and Thomas S. Kuhn (1922–1996) it is possible to create cognitive processes in order to contextualize fundamental questions such as, i.e., *how to acquire a scientific critical knowledge* taking into account the historical and epistemological foundations of sciences (Pisano and Bussotti 2014, 2015d; 2017a; 2017b; Pisano, Fichant, Bussotti and Oliveira 2017;). However, if time is undoubtedly one of the primary and most common constraints – as above cited – we should also mention the actual trend of transmitting knowledge by producing convictions, and not criticism-opinions, is, for sure, a challenge on its own.

As we live in a dynamic world in constant evolution, so it is the case for not only methods and models of science education/teaching science, but also for how students, and courses, which also vary in sociocultural, background and levels, represent to themselves how science and its foundations work; and what is the relationship science technics-technology. For instance, students often consider science as a work of collection of positive (only) discoveries or achievements, one to another, mainly by male and by geniuses (Liouville 1836). All that, by a unique method and cognitive positivist processes, the *scientific method*, which wrongly interpreted in the centuries, leading citizens and young students, closer and closer to the idea of a universal truth: each formula, each law, each principle, axiom and theorem are right, *a priori* because the science. On the contrary, no truth exists in the (history of) science, which is research of how the science work, and not what science is. ~~In fact,~~ Science and history of science, unlike religion, do not answer *Why*, but *How.*

On the other side of the coin, a more tangible down to earth critical question is the question of representations in educational experiments and representational practices in science education. In our era, teaching is more and more centred on new technologies and the web, but no matter what the actual representational vehicles are, their use is to help with the acquisition of a better understanding, to obtain some new knowledge (Reuleaux 1876). The representations (diagrams, icons, images, applets, etc.) are used everywhere, from scientific research to science education, and they are a natural means that allow us to link

[4] Cf. (Bussotti and Pisano 2014, 2017; Bussotti and Pisano 2017).
[5] See: (Pisano, Agassi and Drozdova 2017).

several disciplines. As a (universal) tool, they are the perfect apparatus to explore interdisciplinary teaching and interdisciplinarity in general. Depending on the chosen framework, they provide us with a very fertile environment to work with and on which to raise essential questions. *What about using these scientific representative apparatus and cognitive modelling into the history of science?*

For instance, within a framework of History and historical epistemology of science, one could use the representation of the atom given by the Rutherford model (1911) to make a link to the Arabic juridical tradition that classified three orders of argumentation by parallelism: exemplification, symmetry and analogy; to teach Epistemology, Logics, History of Physics and Physics (Pisano 2017; Pisano and Bussotti 2016). In this particular conceptual window, another link to the History of Physics can easily be made using Sadi Carnot's book *Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance* (Carnot S 1824; Pisano and Gillispie 2014) to illustrate what a symmetry is in the context; since Carnot put in parallel a difference in height to produce work and a difference of heat to produce work:

> From the ideas that have been established so far, we are sufficiently justified in comparing the motive power of heat with that of a fall of water. The motive power in both cases has a maximum value which cannot be exceeded […]. The motive power of a fall of water depends on its heights and on the amount of liquid. The motive power of heat likewise depends on the amount of caloric that is used […]. (Carnot S 1824, 28)[6]

From a methodological standpoint, and within History and Epistemology of science, the argumentation by parallelism plays a fundamental role in solving problems (Rahman and Iqbal 2018). As a core process for scientific reasoning, since the human mind works by association and when confronted to the unknown, we tend to drag back to something better known, it is at the base of science, epistemology and didactics. This main key idea of trying to seek and find scientific-logical similarities in order to draw a parallel between what is meant to be explained and what is already known – which combines heuristic procedures (with which the parallelism is established) and deductive procedures – , thus also providing didactics with an excellent tool for exploring the ins and out of a subject as well as its limits, and finally also providing an invaluable critical mind training. For specific scientific disciplines, it seems necessary to study the role played by images, metaphors, comparisons and analogies in their historical and scientific context as they are an essential part of the scientific framework they are used in. Thus, by introducing this type of analysis, the intrinsic limits of understanding an object within its framework can be overcome by reaching/thinking *out of the box*. In particular, as the end goal is to widen the field of view to reach a better grasp on a concept, object or idea, and because of the argumentation by parallelism's nature, it can easily lead to rich interdisciplinary exchanges which in turn could be a source of complementary discussions. Therefore, the teachers who should be able to navigate

[6] "[…] on peut comparer avec assez de justesse la puissance motrice de la chaleur à celle d'une chute d'eau : toutes deux ont un maximum que l'on ne peut pas dépasser […]. La puissance motrice d'une chute d'eau dépend de sa hauteur et de la quantité du liquide; la puissance motrice de la chaleur [calorique] dépend aussi de la quantité de calorique employé […]." (Carnot S 1824, 28). Translation by Robert Fox in Carnot S 1986, 72; Carnot S 1978, 86; Gillispie and Pisano 2014. See also: (Clapeyron 1834); (Clausius 1850, 1867, 1868-1869); (Joule 1847, 1965); (Fox 1969, 1971); (Lavoisier 1784, 1789 [1937], 1862–1893); (Laplace 1822); (Poisson 1823); (Lamé 1836); (Reech 1853); (Reinhard 1950–1952); (Planck [1897] 1903); (Thomson 1848–1849, 1851ab, 1882–1911); (Mach 1986; Smith and Wise 1989); (Ngô Ch 2009); (Pisano 2007, 2010); (Pisano and Capecchi 2009, 2013); (Pisano and Bussotti 2015b); (Taton 1976); (Pisano, Anakkar, Pellegrino and Nagels 2018).

between different disciplines (interdisciplinary by cognitive and operative mixed aims) and to explain as many times as necessary in many different ways and for different kinds of audiences with different cultural backgrounds are necessarily using such tools and need to be aware of them and how to use them properly as they are forming the next generations of scientists.

On the papers

Thanks to cutting-edge researches done by prominent specialists this collection of contributions represents an outstanding amount of work and thorough analyses of the interdisciplinary environment in constant evolution that is Science Education, and this, always with great respect towards historical context and Nature of Science in mind.

Andrea Amato in "**Knowledge within Anxiety**" explores how the humanity acquires knowledge even though the human being is not able to explicit the reasons behind their "gnosis success". First employing Popper and the transcendental statement concerning the possibility or impossibility of knowing as "trying to guess", then the author argues "whether the reason is the most suitable faculty to ensure the positive development of knowledge". In the paper, the author assumes that the "comparison between theories in terms of their complexities" could indicate us some progress.

Within Arabic-Islamic tradition, "**'Farai sicome tòe amaestrato' (You will Perform, as I Taught You): Notes about Mediaeval Didactics of Algebra**" by **Nadia Ambrosetti** provides a rich analysis and studies of the medieval tradition of the 9th century al-Khwarizmi's handbook on algebra; to solve equations compared with its Latin translation, later translated in Italian vernacular, focusses on the mathematical contents and on the different historical backgrounds and on the teaching style used for them.

Brandon Boesch in "**Representing in the Student Laboratory**" examines the role in science education of the philosophical discussion about the representational practice in science through four case studies. He calls them "educational laboratory experiments". The author also faces three special items: the analysis of how students of science are taught to represent the role of the historical development of these experiments are especially important for the research concerning science education and how to engage students within their disciplines.

In order to get a more comprehensive view of the core subject of this special issue, **Francesco Crapanzano** in "**Strange Trajectories: Naive Physics, Epistemology and History of Science**" presents a renewal in questions related to learning science and mechanics during 1970s and 1980s for those physicists interested in teaching and experimental psychologists before exploring McCloskey studies and "layman physics", by Paolo Bozzi. These compiled pieces of information represent a significant contribution to the History and Epistemology of Science for investigating naïve physics.

Antonino Drago in "**A Suggestion for Teaching Science as a Pluralist Enterprise**" discusses the changes in science education that happened along the past fifty years through four paradigms in a brief, coherent and straightforward manner before exploring the discovery of two dichotomies suggested by the historical foundations of science: a need urge for a renewal in science education. The author shares his suggestions for some innovations to remedy the problems encountered by Physics teachers willing to teach "a truly scientific knowledge" to their students in a very detailed and precise manner.

Andrea Reichenberger in "**How to Teach History of Philosophy and Science: A Digital Based Case Study**" presents the cases of Émilie du Châtelet referring to classical mechanics and relativity theory within the frameworks of history and philosophy of physics. The author considers the integration of women's contributions into the historiography of sciences might function as a critical instrument beyond pure narratives, which is necessary to re-evaluate the historical debate on space and time as presented in classical textbooks by doing a praiseworthy analysis of the complex pattern of change from classical mechanics to the theory of relativity.

Michel Roland in "**What Synergy Between Mathematics and Physics is Feasible or Imaginable at the Different Level of Education?**" explores the apparent growing chiasm between mathematics and physics between degree courses and argues that for interdisciplinarity to take place in secondary schools; its value has to be demonstrated during the future teacher's university education. The author emphasizes on a dual approach, to help students to have a better understanding of the concepts of derivatives and differentials with deductive and inductive inferences (and epistemological obstacles) and sets the stage for a panoramic view of the matter.

In order to elaborate on the technological progress regarding the teaching of science and the newly found advances related to reflections on methods and modelling in teaching sciences, **Logan L. Watts** and **Peter Barker** deliver a profound example of gamification in "**Meeting Galileo: Testing the Effectiveness of an Immersive Video Game to Teach History and Philosophy of Science to Undergraduates**". When empirical research mostly focused on the impact of gamification on the motivation of students, in this paper, the authors analyze the related improvement of taught knowledge as a teaching strategy.

The papers of this IDTC special issue have been independently blind peer-refereed and followed Transversal's review policy. The authors' contributions are in alphabetical order. The editors have respected individual authors' different ideas and historical, philosophical, epistemological an educational/teaching accounts. Therefore, the editor is not responsible for the contents. Each of the eminent authors is responsible for his/her/their own opinions, which should be regarded as personal scientific and experienced background. The authors are also univocally responsible for images, reprints, quotations, acknowledgments, and all related permissions/approvals displayed/not displayed in their papers.

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