Enquiry, Modelling, and Argumentation in Physics Education

Agustín ADÚRIZ-BRAVO

CONICET/CeFIEC-Instituto de Investigaciones Centro de Formación e Investigación en Enseñanza de las Ciencias, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, 2º Piso, Pabellón 2, Ciudad Universitaria, Av. Intendente Güiraldes 2160, C1428EGA, Ciudad Autònoma de Buenos Aires, Argentina

Abstract. In this presentation, I look into the various contributions that the history and philosophy of science can make to physics education, focussing on how these 'meta-disciplines' can be used to construct an educationally valuable image of what I will call the 'nature of physics', that is, an epistemological characterisation of the knowledge and activity in physics. Such characterisation includes the components of enquiry, modelling and argumentation. I will examine the role of these three 'epistemic operations' in physics teaching.

1 Summary

The history and philosophy of science ('meta-sciences') have been inspected by didactics of physics in order to identify in them different contributions for physics teaching. The use of meta-sciences has a long-standing tradition in our scholarly community; along this line, those disciplines have been extensively applied to shape our understanding of the nature of science. In this presentation I advance an educational characterisation of what I call the 'nature of physics' focussing on scientific activity (i.e. 'science as a process'), and using a theoretical perspective that resorts to the idea of *evidence*. From this point of view, I propose that the activity of scientific investigation –at least at school– could be seen as the collection, structuring and use of evidence to understand the natural world. I argue that these three processes can be respectively identified with scientific *enquiry*, *modelling* and *argumentation*.

My characterisation of the nature of physics adds to 'mainstream' research on the nature of science (NOS9 three other foci of investigation and innovation present in didactics of physics. The first focus is *scientific models and modelling*. Although models have generally been addressed in didactics of physics from a psychological and cognitive perspective, there is some emergent literature analysing the *epistemic* nature of scientific models, and drawing implications for physics education. The second focus is what I call *school scientific argumentation* (i.e. the use of arguments in school school). Here the connections with NOS research have been scarce (apart from the use of Stephen Toulmin's argumentation pattern); nevertheless, some authors have recently begun to inspect epistemic criteria to argue in science, or the role of scientific models when constructing and using arguments. The third and last focus is *enquiry-based science teaching*. In this case, the relationships with NOS research have been more ambiguous, ranging from lack of meta-theoretical input in enquiry literature to 'parallel', and rather independent, characterisations of the nature of science and the so-called 'nature of scientific enquiry' (or NOSI).

In this presentation, I seek to identify fruitful connections between the nature of science, on the one hand, and models, argumentation and enquiry, on the other, using theoretical contributions from a diversity of scholars, with special attention to the literature in Latin America.

Didactics of physics has contemplated the nature of science in general, and of the discipline in particular, from a broad range of theoretical perspectives. In this sense, it has been repeatedly pointed out both by philosophers and didacticians that there is no such thing as 'one' nature of science. Literature reviews show that NOS can be construed in quite dissimilar ways: as a list of general tenets or a set of philosophical models, and focussing on specific issues such as demarcation, experiments, values, explanation, gender, etc. For this presentation, I have chosen a semantic, model-based, approach, taken from the philosophy of science of the last three decades, which has helped me in identifying fruitful links between NOS, and models, argumentation and enquiry.

Physics is constituted by a set of products: not only knowledge, but also methods, values, data, artefacts, publications, etc. But, on the other hand, physics comprises a manifold of *processes* carefully designed and adjusted in order to generate those products. Among scientific processes, I include innovation, justification, systematisation, application, evaluation, and communication. In coherence with this, I locate scientific investigation under the umbrella of processes, but not conflating it with science-in-the-making as a whole. The term 'investigation' comes from the Latin 'investigare' with the meaning of *follow trails*; it is connected to the English word 'vestiges': traces, marks, signs, and –more concretely– footprints. This etymological connection can be profitted from a didactical point of view: when teaching physics, it can be interesting to highlight the problem-solving, evidence-based, nature of the discipline.

Scientific activity says things about the world, and demands reasons to sustain what is being said. *Investigation can be intimately connected to the idea of evidence*: when doing science, scientists produce or obtain –via different 'methods'– 'compelling' elements in favour of our understanding of the real world. In my proposal, school scientific investigation is defined as the collection, structuring, and use of evidence in order to *give support* to a scientific view on a natural phenomenon.

My conceptualisation of the nature of physics also gives centrality to scientific explanation, locating it at the top of the hierarchy of epistemic purposes of science. In order to explain, it can be contended that there is a converging use of models and argumentation. Models give *intelligibility* to evidences; those highly systematised evidences are later used in elaborate scientific arguments to show how some carefully selected phenomena are 'good cases' for a particular theoretical view.

I assume that the three epistemic processes (enquiry, modelling, and argumentation) that I am examining in this presentation are founded on evidence-based *inferences* (i.e. modes of reasoning or thinking); such inferences can be grouped under the label of *abduction* in its most general sense, also known as 'inference to the best explanation'. That is why I am particularly interested –in my theoretical and practical proposal, directed to physics teachers– in drawing an analogy between scientific reasoning and detective, medical, forensic, and 'gossipographic' (garden-variety) thinking. In all these fields, a parsimonious collection of 'facts' gathered under the guide of a strong model can be used as premises of a logically 'ampliative' reasoning pattern, which 'ascends' to general, abstract, and extremely audacious conclusions with explanatory power.

The core of my presentation will be devoted to examining the role of models in the nature of physics. Recently, didactics of science has provided *model-based* or *model-theoretic* portrayals of the nature of science. Such portrayals, usually transposed from the so-called *semanticist family* of contemporary philosophy of science, *explicitly* depict school scientific theories as families of 'theoretical models', and school scientific investigation as a process of modelling (i.e. constructing and using models to represent and intervene), I find such portrayals instrumental to construct an educationally valuable image of physics for the physics classrooms of the different educational levels and for physics teacher education.