Multi-Contextual Approach of History of Science (MCAHS): Introducing Historical Content in Science Teacher Training

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Introduction

This paper presents a proposal for introducing historical content in science teacher training courses using the Multi-Contextual Approach of History of Science (MCAHS), developed by the authors within the our research group, the Group of History, Theory and Didactics of Science. . The MCAHS proposal is based on the teaching of historical episodes through three interconnected contexts: *scientific*, *meta-scientific* and *pedagogical*. By this approach, we intend that pre-service teachers recognize the importance of HPS contents to explore an adequate view of Science and its use to contextualize scientific concepts. Moreover, future teachers might develop pedagogical skills necessary for the introduction of meta-scientific contents in their teaching. MCAHS teaching module were applied with pre-services physics teachers in Brazil and the results of this pilot application indicates that the participants became more involved with HPS contents and developed a more critical and transformative attitude towards their future teacher practice and education in general.

The present paper is divided in three parts: firstly, we discuss the structure of MCAHS proposal, briefly pointing out the authors used to support it; secondly, we discuss two examples of how historical episodes were analyzed by MCAHS proposal in the pilot application in Brazil; thirdly, we finalize discussing the perspectives for the development of the proposal and its future applications in science teacher training courses.

Multi-Contextual Approach of History of Science (MCAHS)

The Multi-Contextual Approach of History of Science was developed in a wider context of research, involving not only the use of HPS in science teacher training, but the concept of critical and transformative education of teachers (Moura 2012). Critical and transformative teachers are defined as those who dialogues critically with the world and understands their roles as educators of citizens that also need to dialogue critically; they can establish interdisciplinary connections between scientific knowledge and other areas and

comprehend the historical process of the development of Science and its cultural importance to society. We indicate that the study of History of Science is a possible way, but they note that simply introducing historical content is not enough; it is necessary a rethinking about how we incorporated it in science teacher training courses.

The MCAHS approach is based on the concept of contextual teaching and is constituted by two main imbricate elements: the historical episodes and their contexts of analysis. The historical episodes are defined in MCAHS approach as a set of interrelated events that has a central aspect in common. By this perspective, it is possible to conceive different kinds of historical episodes, since the ones that occurred in a short period of time or that involved a few number of people, to the ones that occurred in a long period of time and linked the ideas of several individuals.

The historical episodes are studied by a problematization view (Freire 2000), which means that the discussions about History and Philosophy of Science within MCAHS proposal take into account aspects that can be treated as problems, so that pre-service teachers become more motivated to embrace the study of History of Science and understand its potentiality as pedagogical resource for their future teaching practice. As the pre-service teachers become inquirers, they enlarge their critical thinking skills and develop a transformative attitude (Moura 2012, p. 228).

The contexts that constitute the MCAHS proposal are dimensions by which the problems from the historical episodes are analyzed; they are perspectives of analysis that, in an integrated view, gives meaning to the whole episode. Therefore, the contexts are the way by which is done the resolution of the problems coming from the historical episode. The MAHS proposal emphasizes three contexts: *scientific, meta-scientific* and *pedagogical*.

The *scientific* context considers the scientific concepts of the historical episodes, by a practical and a theoretical angle. The study of the historical episode by the *scientific* context intends to make clear the origins, structure and validity of the scientific concepts inside the episode, highlighting that scientific knowledge is historical and mutable, thus offering a better understanding of nature of science. We intend to overcome the traditional view that scientific concepts are just rules to be memorized, but understand them as result of a historical process, constantly subject to change.

The practical analysis of scientific concepts in MCAHS proposal works on the experimental questions involving the concepts, especially using the historical representation method (Metz and Stinner 2006). Then, the study of experimental aspects involved in historical episodes is concentrated on the ideas and procedures adopted by scientists, not the exact reproduction of materials and conditions of historical experiments. We assume that the study of the process of a historical experiment is an opportunity for the pre-service teacher to understand key aspects of a historical episode and possible influences of metascientific ideas, the use of different methods – in contrast with the "universal" scientific method –, the changing of ideas, among others.

The theoretical analysis deals with the internal structure and validity of scientific concepts. We believe that simply presenting a superficial approach of a historical episode – or a historical experiment –, without discussing the theoretical details is quite unproductive. The adequate understanding of a scientific concept can only be done when we analyze its origins and development, otherwise we have just an imposition of ideas. Besides, the study of scientific concepts by the theoretical analysis shows the changing character of Science, mainly when we discuss obsolete ideas and why they were valid at a certain period.

Therefore, the study of historical episodes from the *scientific* context, both by a experimental and a theoretical approach, can illustrate the structure and validity of scientific knowledge, which are some of the necessary requirements for the adequate use of History and Philosophy of Science in teaching practice.

However, the analysis of a historical episode from the *scientific* context might only emphasize an internalist view of History and Philosophy of Science (Kragh 1987). Thus, in order to give a wider view of it, it is necessary to interconnect the study of the episode from the *scientific* context with the analysis of external influences, stressed by the *meta-scientific* context.

The *meta-scientific* context underlines the mutual influence of historical, epistemological, philosophical, sociological and cultural aspects over the episode. These aspects are frequently understood as Nature of Science, or NOS (Lederman 1992). In literature, many authors have dedicated efforts to discuss students and teachers' views of NOS and to propose new approaches to incorporated adequate NOS understandings, including with History and Philosophy of Science (Silva and Moura 2012; Forato et. al. 2012; Abd-El-Khalick and Lederman 2000; Irwin 2000; McComas et. al. 1998, among others). In MCAHS proposal, the investigation of historical episodes from the *meta-scientific* context bases on the explicit discussion of NOS (Abd-El-Khalick and Lederman 2000, p. 1088), so that pre-service teachers know which of them can be better illustrated by the episode.

Learning NOS aspects by an explicit view can facilitate an accurate perception about Science and the external influences that act on it. For example, by understanding that the development of scientific knowledge is not only a matter of experiments and theories, but also of agents that exceed the internal limits of Science, pre-service teachers can enhance their critical view about how Science – and Physics – is, nonetheless, a historical construct.

It is well known among researchers in the field that besides the obstacles concerning the introduction of History and Philosophy of Science contents in Physics/Science teachers training programs, there are also the problems about the effective use of them by future teachers. Monk and Osbourne (1997, p. 411), for instance, argued "that the failure of HPS to contribute to mainstream of science teaching is because teachers have no confidence that a historical context adds anything to their students' examinable knowledge and skills". Therefore, simply trying to incorporate historical content seems to be sterile. Forato and collaborators (2012), by establishing parameters to introduce History and Philosophy of Science in High School classrooms, highlights the general lack of teachers' skills to deal with

historical content. The authors mention that "overcoming this obstacle is not something that can be done in a short period".

Höttecke and Silva (2011) addresses some other obstacles for the implementing of History and Philosophy of Science that influences their use by teachers. According to them, besides the fact that teachers generally do not have necessary skills to work with historical content, their epistemological beliefs about Science and conceptions about the process of teaching and learning constitute a barrier that is not easily overcome. The problem of incorporating historical content in teachers practice is also a cultural question that need to be considered in training.

Therefore, if we intend not only to introduce adequate views of History and Philosophy of Science to teachers, but also that they effectively use it in their teaching practices, it is imperative that they can reflect about it. The integrated view of historical episodes from MCAHS proposal is finally completed by the *pedagogical context*. It consists of moments when pre-service teachers experience teaching strategies and reflect about the use of the historical episode in their future teaching practices. These moments involves the reflection of questions like: "*how* to use History and Philosophy of Science in my classrooms", "*how* to use an episode as a problematization resource to a better teaching", "*how* to gather all of the potentiality of historical content to facilitate the process of teaching and learning". By the *pedagogical* context, we believe that teachers can develop some of the necessary skills to work with History and Philosophy of Science, overcoming the traditional conception of teaching and learning.

The pilot application in Brazil: two examples of historical episodes analyzed by MCAHS proposal

The Multi-Contextual Approach of History of Science (MCAHS) passed through a pilot application with pre-service Physics teachers in Brazil. We chose a specific discipline that intended to work with them the use of History and Philosophy of Science contents in High School education. The complete description of the pilot application is available in Portuguese (Moura 2012).

For the pilot application, we selected four historical episodes of optics and electromagnetism which were analyzed by MCAHS proposal with pre-service teachers. Here we present two of them: Newton's experiments with prisms and the heterogeneity of light and the discovery of electromagnetism.

As we pointed out above, the historical episodes were studied in MCAHS proposal by a problematizing view, which means that pre-service teachers are faced with a problem or question to solve. In the pilot application, the problems or questions enfolded selected aspects of Nature of Science (NOS) evidenced by the episodes. Therefore, the problematized element was part of the *meta-scientific* context.

The episode concerning Newton's experiments with prisms and his concept that light was a heterogeneous mixture of coloured rays is one of the most remarkable in history of

optics. As a fine example of the complex interplay between hypotheses and experiment, this episode illustrates the experiments Newton designed and hypotheses he elaborated in order to show that white light was not homogeneous, as almost the entire community of seventeenth century natural philosophers thought. The main purpose for discussing this episode with pre-service teachers was the possibility to understand how Newton thought light would be and how he wisely made use of experiments and epistemological argument to explain what the prisms do when a beam of light passes through them. Accordingly, pre-service teachers can comprehend that these experiments are not simple, contrary to the idea that they are easily reproduced, what many didactic materials and academic works usually point (Martins and Silva 2001).

The episode was discussed with pre-service teachers in two correlated parts. The first one involved the publication of Newton's "New theory of light and colours" (Cohen and Schofield 1978, p. 47-59) in 1672. In this paper, Newton discussed the composition of white light after it passed through a prism of glass. He concluded that white light as a heterogeneous mixture of coloured rays, taking as prove the results of the *experimentum crucis*. Basically, the experiment consisted of making a beam of white light pass through two prisms. Passing the first one, white light would be divided into several coloured beams. Then, by a hole in a small board, Newton let just a small part of the spectrum passes to the other prism. This secondary beam was then refracted by the other prism, when nothing but another deviation of it was observed. For Newton, it was demonstrated that the prism did not modified a homogeneous white light, as It was generally believed; instead, the prisms only separate coloured rays that compose white light, according to their different degrees of refrangibility. The second part involved the content of *Opticks* (Newton, 1979), specially Book I, wherein Newton made a more detailed and extended analysis of the experiments with prisms and presented a study about the colours of objects and other related issues. We gave emphasis on the different approaches of the *experimentum crucis* in the "New theory" and Book I, in which it played just a supporting role.

For this episode, we selected as the problematizing element the following NOS aspect: scientific theories are not build up only from inductions, but also by hypothesis, which go imaginatively and necessarily beyond observations (Pumfrey 1991, p. 69) and epistemological arguments. This aspect was transformed in these questions: "Did Newton only base on experiments to conceive the heterogeneity of light?" and "What was the exact role of the *experimentum crucis* to the development of his conceptions?"

In order to solve the initial problem, the episode was studied by the contexts of MCAHS, in the following manner:

- *Scientific*: pre-service teachers studied the concept of heterogeneity of light by reading and discussing the content of the "New theory of light and colours". Combined with this theoretic discussion, we analyzed experimental aspects of the episode, such as the role of minimum deviation position and of the *experimentum crucis*. Pre-services teachers was, then, aware of Newton's choices and could comprehend the difficulties concerning the performance of these experiments.

- *Meta-scientific*: in this context, pre-service teachers studied the interdependency of theories and experiments, specially the role of hypothesis in Newton's conceptions. Despite his well-known advocacy against hypothesis, Newton did use them to substantiate his theory of light and colours.
- *Pedagogical:* In this context, pre-service teachers discussed how this episode could contribute to the teaching of nature and heterogeneity of light and how it could be used to problematize the widespread inductivist view of scientific method. Pre-service teachers also developed didactic materials to teach concepts of optics using this historical episode as background.

The other episode – the discovery of Electromagnetism – discussed the contribution of Hans Christian Ørsted (1777-1851) to the understanding that electric and magnetic phenomena are related. On the other hand, historical studies had shown that his contribution was far from being only a discoverer, once he also elaborated a model based on the circular magnetic effect to explain the phenomenon he analyzed.

In 1820, during a class, Ørsted noticed that a magnetic needle was disturbed when a conducting wire with an electrical current was placed parallel above it. After a careful study of the phenomenon, he concluded that the electric current produced a circular magnetic effect, then elaborating a model based on the conflict between negative and positive electricity. A complete account of Ørsted discovery – including some controversial points – can be found in Martins (2003) and Kipnis (2005).

The episode was discussed in two parts in the pilot application. First, we explored the context in early 1800's, showing that many researchers were trying to understand the relation between Electricity and Magnetism. We also discussed the influence of *Naturphilosophie* over Ørsted's ideas (Gower, 1973), remarking that he had philosophical reasons to establish this relation. In the second part, we reproduced Ørsted's experiment with low cost materials, explaining why he ended up elaborating a model based on the circular magnetic effect of the current.

This episode is rich in interesting NOS aspects; among them we chose the influence of philosophical ideas on Ørsted's thoughts and attitudes. This aspect was used as an initial problem, in the form of questions such as: "Was the discovery of electromagnetism made by chance?" and "why did Ørsted set the wire parallel to the magnetic needle?"

In order to solve the initial problem, the episode was studied by the contexts of MCAHS, in the following manner:

- *Scientific:* pre-service teachers studied the phenomenon with a historical representation of the experiments performed by Ørsted and his original notes and reviews about the discovery (like the description in the *Encyclopedia of Edinburgh*, in 1827), so comprehending the reasons behind his choices;
- *Meta-scientific:* in this context, the influence of *Naturphilosophie* concepts over Ørsted's thoughts was studied.

- *Pedagogical*: in this context, the pre-service teachers underwent two different activities. Firstly, they debated how the episode could be used in classroom to teach and problematize some concepts of electromagnetism – such as, the circular magnetic effect and symmetry – and about the aspects of NOS that could be discussed, like the influence of non-scientific ideas on scientists thoughts and the "chance" in science. Secondly, pre-service teachers were asked to produce a didactic material to teach concepts of electromagnetism using the historical episode.

Final remarks

In this short communication, we presented the basic structure of Multi-Contextual Approach of History of Science (MCAHS), designed to be used in teacher training programs. The pilot application in Brazil showed that MCAHS had brought a new perception of History of Science by pre-service teachers who attended the research. Data obtained indicated that pre-service teachers showed a better tendency to use adequate historical content in their practice.

However, it is important to underline that MCAHS is not a closed proposal. As any proposal for Education, it is open to further changes, adaptations and improvements. One challenge is to bring MCAHS proposal to in-service teachers and high school students, with the proper adaptations. The adaptable and open structure of MCAHS enables different kinds of uses, not only in specific disciplines of History and Philosophy of Science in teacher training courses, but also along the discussion of Physics contents.

The relation between History and Philosophy of Science and teacher training has much to be developed. Introducing and improving MCAHS proposal could overcame some vital problems that educators and trainers face, such as the lack of skills and affinity with historical content of teachers. This is a long discussion, but MCAHS proposal offers some ways to continue towards solutions.

Bibliography

Adb-El-Khalick, F.; Lederman, N. (2000). The influence of history of science courses on student's views of nature of science. *Journal of Research in Science Teaching*, 37 (10), 1057-1095.

Cohen, I.B., Schofield, R.E. (eds). (1978). *Isaac Newton's papers & letters on natural philosophy*. Cambridge, MA: Harvard University Press.

Forato, T.C.M., Martins, R.A., Pietrocola, M. (2011). History and nature of science in high school: building up parameters to guide educational materials and strategies. *Science & Education*, 21 (5): 657-82.

Freire, P. (2000). *Pedagogy of the oppressed.* London: Bloomsburry Academic.

Höttecke, D., Silva, C.C. (2011). Why implementing history and philosophy of Science is school science education is a challenge: an analysis of obstacles. *Science & Education*, 20 (3-4): 293-316.

Irwin, A.R. (2000). Historical case studies: teaching the nature of science in context. *Science Education*, 84 (1): 5-26.

Kipnis, N. (2005). Chance in science: the discovery of electromagnetism by H.C. Ørsted. *Science and Education*, 14, p. 1-28.

Kragh, H. *An introduction to the historiography of science.* Cambridge: Cambridge University Press, 1987.

Lederman, N. (1992).Student's and teacher's conceptions of the nature of science: a review of the research. *Journal of Research in Science Teaching*, 29 (4): 331-59.

Martins, R.A. (2003). Resistance to the discovery of electromagnetism: Orsted and the symmetry of the magnetic field. In: Bevilacqua, F.; Giannetto, E. *Volta and the history of electricity*. Pavia/Milano: Università degli Studi di Pavia, Editore Ulrico Hoepli.

Martins, R.A., Silva, C.C. (2001). Newton and colour: the complex interplay of theory and experiment. In: Bevilacqua, F.; Giannetto, E. & Matthews, M.R. (eds.). *Science education and culture: the contribution of history and philosophy of science*. Dordrecht: Kluwer Academic Publishers.

Matthews, M. (1994). *Science teaching – the role of history and philosophy of science*. New York: Routledge.

McComas, W. F., Almazroa, H., & Clough, M. P. (1998). The nature of science in science education: An introduction. *Science & Education*, 7(6), 511–532.

McComas, W.F., Almazroa, H., Clough, M.P. (1998). The nature of science in science education: an introduction. *Science & Education*, 7 (6): 511-32.

Metz, D., Stinner, A. (2006). A role for historical experiments: capturing the spirit of itinerant lectures of the 18th century, *Science & Education*, online version.

Monk, M.; Osbourne, J. (1997). Placing the history and philosophy of science on the curriculum: a model for the development of a pedagogy. *Science Education*, 81: 405-24.

Moura, B. A. (2012). *Formação crítico-transformadora de professores: uma proposta a partir da História da Ciência* (Critical and transformative education of physics teachers: a proposal from the History of Science). PhD Thesis. Instituto de Física, Universidade de São Paulo, São Paulo.

Newton, I. (1979) *Opticks or, a treatise of the reflections, refractions, inflexions and colours of light*. New York: Dover.

Pumfrey, S. History of science in the National Science Curriculum: a critical review of the resources and their aims. (1991). *British Journal for the History of Science*, 24 (1): 61-78.

Silva, C.C., Moura, B.A. (2012). Science and society: the case of acceptance of Newtonian optics in the eighteenth century. *Science & Education*, 21 (9): 1317-26.