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History of Chemistry as a strategy in Teacher Education

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Introduction

The History of Science, if understood within the framework of post-positivist epistemologies, helps to clarify contextual aspects of the construction of science and contributes to its understanding as an element of culture for responsible citizenship. Including the History of Science in teaching strategies may contribute to the demonstration of a more realistic picture of the relationships between science, technology and society and thus to the view of science as a human activity (Hodson 1998; Niaz & Rodríguez 2000). We might remember the History of Science that is needed in science education, as Monk & Osborne (1997) state: "not a sanitised history of fully developed ideas, but the history of how those ideas were developed, of the people who created them and how they impacted on society". It is a History of Science philosophically reflected upon (Matthews 1990; Jensen & Finley 1995).

What we think about science is influenced by what we learnt both in formal (school) and informal contexts. In a culture where dogmatic ideas of science are frequently disseminated, teachers may find it rather difficult to teach young people to have an understanding of science in line with the contemporary Philosophy of Science. On the other hand, science teachers themselves frequently conceive their teaching within the framework of empiricist epistemologies. In Portugal, Praia and Cachapuz (1994), showed the predominance of empiricist views held by nearly 2/3 of a sample of 464 secondary teachers (irrespective to the teaching subject and professional experience). Chemistry teachers are no exception and the authors suggest the need for adequate courses both in pre-service and in-service teacher education.

Aims and hypothesis of the study

The aim of the study was to design, implement and evaluate a model of teacher education centred in the History of Chemistry which provides chemistry teachers with
an understanding of the educational relevance of post positivist epistemologies of science in their lesson planning and teaching of the topic “mass conservation in chemical reactions” (low secondary school, 14/15 year olds).

The main hypothesis of the study was that it is possible to change the images of science/chemistry transmitted by classroom teachers through adequate in-service courses centred on lesson planning and reflection on their teaching of a topic with strong historical roots.

Methodology
The research followed a longitudinal approach (3 years) and the methodology basically had a case study research orientation. The study consisted in three articulated steps: a naturalistic step, and two subsequent steps involving the participation of teachers and researchers working together in an action-research program.

The analysis of teachers’ practices was supported by a theoretical instrument previously developed and based on the framework of the New Philosophy of Science (Paixão, 1998), (see Fig 1).

The Teacher Education Program based on the History and Philosophy of Science
A key aspect of the approach followed was the choice of an epistemologically relevant topic from the chemistry syllabus with strong historical roots. In this study the chosen topic was "mass conservation in chemical reactions", and the historical controversy which accompanied the establishment of a general theory of chemical reactions, where the principle of mass conservation guided Lavoisier. At the same time we took in consideration biographical aspects of Lavoisier in his time (the eighteenth century and the French Revolution); the scientific community and his direct opponents, particularly Priestley, the role of his wife in the laboratory, his work as the director of a gunpowder factory and as a tax controller and collector; his personal fortune and the investment in special balances and other sophisticated lab material... The way he registered all the experiments he did and the initial ideas and reflections about the results obtained. Also his death, when he was only 50 years old, for political reasons related to his professional activity.
<table>
<thead>
<tr>
<th>Epistemological Categories</th>
<th>Analysis Dimensions</th>
<th>Teaching Practice Indicators (examples)</th>
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<tr>
<td>I – Scientific methodology</td>
<td>A - Methodological pluralism</td>
<td>Explicit references to some episodes of the HS and/or current aspects of scientific investigation with relevance to different scientists' working methods. Discussion of students' ways of working with clarification of the means of selecting experimental proceedings and their adequacy and/or limitation (not recipes).</td>
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<td>B - Theory / observation / experiment relations</td>
<td>Theoretical considerations before observation and experiments. Initial problematic questions and predictions. Critical report of the Experimental Work orientated by problematic questions and including critical assessment of the results</td>
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<td>II – The dynamics of scientific knowledge construction</td>
<td>C - Scientific discovery: Context and structure</td>
<td>Activities exploring historical controversies in the establishment of a respected scientific theory (i.e. texts and related questions)</td>
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<td>III – The human and social side of science</td>
<td>E - Images of scientists and the scientific community</td>
<td>Explicit references to the human side of scientists. Opportunities for the students to express their own ideas and confront them with their colleagues' ideas and/or with the current scientific version.</td>
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<td>F - STS interrelations</td>
<td>To begin with a social or a technological problem. To promote intentional discussions (debate) about science related questions, showing the relation between science and technology, and ethical or environmental questions... with the opportunity for students to express their established ideas.</td>
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Figure 1 - Instrument of teaching practices analysis
Worthy of note too, is the importance of this theme in the present social and technological context, in relation to aspects about which the students should form well-grounded and critical opinions. For example, in Portugal at the moment there is much discussion about using the co-incineration process for toxic waste in cement factories. The problem is the eventual toxic gases emission or the remainder toxic particles into the commercial cement.

The teacher education was structured in three interrelated steps:

The first step, aimed to identify and to characterise difficulties experienced by two chemistry teachers to integrate adequate epistemological perspectives in their teaching. The teachers were volunteers; they had different academic training and teaching experience and came from different schools. The first step consisted of the video-recording (naturalistic setting) and analysis of classroom practices of the teachers involved. The results of this step were later explored to support teacher reflection; these results also helped to establish a comparative analysis of the evolution of each teacher throughout the program and thus to aid on the internal evaluation of the study.

The second step, aimed to properly educate the teachers through preparation and discussion of selected teaching materials. It involved the joint work of researchers with the teachers exploring that part of the History of Chemistry related to the mass conservation topic and discussing with the teachers relevant aspects of the context of the discovery, planning the objectives, possible teaching strategies and activities to be developed with students. More specifically, it included the reading and critical analysis of texts (adapted or translated from the originals of the time, biographical texts...) the construction and discussion of questions about the texts, the preparation and analysis of experimental protocols based on the experiments carried out by Lavoisier and his collaborators, the preparation of laboratory equipment, simulations, the selection of relevant bibliography about that time, scientific community controversies...

This planning constituted the core of the training step in the History and Philosophy of Science. The reference to theoretical authors (Popper, Khun, Lakatos...) and discussion of main epistemological issues was always made based on teaching contexts. We felt this strategy helped teachers to appreciate the relevance of epistemology for their teaching.

The third phase, involved applying (in the following year) the previous planning to the teaching of mass conservation in chemical reactions (with different students). The researchers were always available and guided the application of the planning. As in the
first step the lessons were video-recorded (nearly 12 hours for each teacher), transcribed and analysed by researchers and by teachers aiming to characterise the evolution of each teacher.

Results and Discussion

Evidence of the evolution of the teachers' practices are synthesised in Fig. 2 according to the categories of analysis previously defined: scientific methodology; dynamics of the construction of scientific knowledge and the human and social face of science. The inferences made by the researchers were complemented with arguments from the two teachers. For example:

Teacher A:

Until now... I hadn't given much thought to this, or let's say I hadn't thought how really important it is, the way science has evolved and the work it takes to arrive at the concepts that you give them there... with nothing else!

All the more so because the pupils, especially in the 8th grade, are used to having things "served up on a plate"... they don't even imagine the work it took to get that far... so they will definitely value science much more if they see how it evolved over the years. So... and... I think that putting science into context, the History of Science, is very important

Teacher B:

[The pupils realised how difficult it was to change a scientific theory] I think they realised that. You can see it in the presentation of the final texts when they said that Priestley himself discovered oxygen or helped to do the work... and he always defended the phlogiston... They realised that.

Even concerning the experimental method... the last one (training text) which I thought was interesting and which I was reading... I think so (...) because the experimental method, we said that... that sequence, whether it's correct, etc..

The two teachers who participated were unanimous in affirming the education value of the TEP. Students' opinions were equally positive:
It was a different way of learning

The teacher gave us a lot of handouts even on the evolution of ideas. She didn't just arrive and tell us what it was.

It wasn't easy for him [Lavoisier] either to arrive at that theory.

Also, we'd never been in a situation like that. This was something that got us more interested. And it was more... it was different!... And that way we had other methods.

We... even outside, between lessons, after the Chemistry lessons, we talked about that and... we really talked... and discussed those problems...

Conclusions

The conclusions can be presented in two main related aspects:

(i) - The teachers' epistemological perspectives in the first phase reveal simple realism, an empiricist tendency to valorise observation and experimentation. They transmitted an image of science which is neutral, dogmatic, linear, without structure and without history; scientific knowledge was presented as an absolute non-problematic truth. Teachers' concerns were centred on the pedagogical aspects of order and discipline in the classroom, on aspects which, apparently, make the subject advance in the desirable way.

(ii) – The new epistemological perspectives of the teachers after the training period. The analysis made of the third phase suggests that the two teachers were able to transmit more rationalistic science views, emphasising the role and the value of theory, prediction and experiment. The dynamics of the construction of scientific knowledge was also highlighted. The History of Chemistry was emphasised as well as the STS interdependence. Clearly there was an evolution from a simple realist perspective to a more critical and contextual realism, from empiricist to post-positivist epistemologies. Thus we may conclude that an epistemological education of teachers, by supporting the use of the History of Science as a teaching strategy, contributes to a change in the images of Chemistry transmitted to the students, images which are more in line with the framework of the New Philosophy of Science.
The teachers realised that the main lines of the approach followed can be extended to the teaching of other chemistry topics making learning more meaningful for the students.

As evaluated by the two teachers it is a promising model for in-service teacher education.

References:


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<thead>
<tr>
<th>Teacher A</th>
<th>Scientific Methodology</th>
<th>Dynamics of Scientific construction</th>
<th>The Human Side of and Social Science</th>
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<td>Before</td>
<td>After</td>
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<td>After</td>
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<tr>
<td>- Linearity of ways of work beginning with observation/experiment</td>
<td>- In EW there are always guiding questions which serve as a guide for the activities to be developed. The theory serves as orientation for the experiment. - A historical parallel is noted. - Abundant reference is made to the way scientists and scientific communities work. - An interpretation of the results obtained is required. - An image of science is associated with rationalistic perspectives.</td>
<td>- Valuartion of definitions and factual knowledge of science. - Static and cumulative knowledge, without structure for discovery and a-historie. - The aim is always to obtain &quot;correct answers&quot;. - Non-perception of pupils' misconceptions. - Position of simple realism.</td>
<td>- The importance of the HS is highlighted and the process of scientific knowledge building is valorised. The resources used are justifed in parallel with HS and cultural contextualisation of Lavoisier's time, from a more internalistic perspective. - Image of the temporary validity of a theory for interpreting phenomena and for providing solutions to problems. - Diverging opinions are accepted. - Problems and conclusions of the EW are shared.</td>
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<td>Teacher B</td>
<td>Abundant variety of proposed tasks and complementary activities.</td>
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<td>Non-contextualization of the theories presented.</td>
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<tr>
<td></td>
<td>- The importance of HS is highlighted and the course of scientific knowledge building is valued. Many biographical and contextual aspects are introduced.</td>
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<td>- The temporary validity of a theory is highlighted.</td>
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<td></td>
<td>- The pupils' misconceptions which arise in the lesson are identified.</td>
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<td></td>
<td>- Movement away from the perspective of simple realism.</td>
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<td></td>
<td>Movement away from the perspective of simple realism.</td>
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**Figure 2 – Evolution in the teaching practice of the teachers**

- Discussions between pupils with different ideas are encouraged.  
- Idea of the need for social recognition of the work of scientists in the building of scientific knowledge.  
- The contribution of various collaborators to the work developed by Lavoisier is considered.  
- The introduction and development of the theme done from a STS perspective with evidence of interrelated aspects.
"Radiation and Environment" a regional theme for the improvement of the Scientific Culture of a School Community

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Abstract

The aims of the present study were to assess the environmental and radiation awareness of school children and to evaluate the effectiveness of an educational program on these issues. A mixed-methods approach was used, combining quantitative and qualitative data. The study was conducted in two phases: before and after the educational program. The results showed a significant increase in knowledge and awareness among the students. The program was considered successful and recommended for further implementation. The importance of environmental education and its role in promoting a sustainable lifestyle was emphasized.
An Experimental Work Project with STS Orientation: Dyes and Dyeing in a Regional Context

Introduction

Castelo Bruno is a small town in inland Portugal with a unique kind of embroidery of eastern inspiration. Dyed silk thread of different colors is used to embroider onto linen, and motifs, colors, and techniques used make it easily identifiable. Today, these embroideries are considered a tradition of great cultural and economical value for the region and there is a training workshop in the town's Museum where the embroidery is the main focus. Also in the region, textile industries of great national importance were established more than two centuries ago, to which dye-worx were an important feature. Although for a long time, the silk thread was dyed with natural dyes obtained from plants and animals such as indigo, woad, madder, grape, valerian, yellow lilies, madder... Today, these have been almost completely replaced by synthetic equivalents.

This context was the starting point for the development of an innovative experimental work project called "Viva'Living" Science with students from several lower and upper Secondary Schools of the Castelo Bruno region.

Objectives

- To develop a better understanding of the Chemistry involved in the dyeing process, including the use of laboratory techniques of analysis and synthesis and how to extract dyes from the natural products and to synthesize dyes themselves.
- To identify some of the colors used in the embroidery from extracted authentic synthetic dyes.
- To reidentify the embroidery of Castelo Bruno as a cultural and historical heritage with economic potential associated with a tourististic activity.
- To establish links between education and research e.g. secondary schools and a research center.
- To establish links between the school and the community.

Students' opinion

- The synthetic dye "validil" provides the colors and the colors of the embroidery from the XIX and XXI centuries. It's a very interesting to see the dyes and see the results, quantifying the analysis.
- We get a better understanding of fiber and textile aspects.
- This work is very important for us since it included the integration with cultural and artistic views.

Developed Project Activities

An oriented visit to the Embroidery Museum was done to enter to give a contextualized starting point to the experimental work developed by the students in the secondary schools.

- Work groups search on plants traditionally used for dying silk of the embroidery, their chemical groups and colors after characterization they presented posters in the common room.

Dyeing with allizarin-mordants!

- The silk is immersed in water with 1% of esmuna and two drops of detergent.
- The fibers are placed in 0.01 M solution of NaNO₂, 0.01 M CO₃⁻, 0.01 M Na₂CO₃, and H₂SO₄.
- The silk is immersed for each mordant solution and heated with H₂SO₄.
- The dye is heated with water and gently warmed (60°C).
- The silk and the mordant solutions are then added to the pink allizarin-mordant.

- Result: green, red, orange, brown, and dark colors have been obtained.

To the Chemistry Research Centre the students had the opportunity to visit the Organic Chemistry of the University of Coimbra, which is a very fascinating learning experience. The students were able to see and analyze the equipment and techniques previously prepared to their schools. They could demonstrate chemical techniques of analysis with the detection of contaminants in different solutions and environmental control perspective.

Selected Examples

From the Experimental Activities

Natural products extraction

- The pigment is from the flower family with the initial state generation and it can easily be extracted by boiling the flowers in water.

- In the second part of the work the silk was dyed by direct immersion in the dye solution.

Synthesis of Azo Dyes

- a) In a flask Illinois dissolved in concentrated HCl.
- b) A water solution of sodium nitrite is added dropwise in the aqueous solution of HCl, that gives the diazonium salt solution.
- c) The diazonium chloride salt is then added to a solution of formaldehyde with sodium hydroxide solution of formaldehyde and water.
- d) The solution is poured into a beaker and stirred with a magnet.
- e) The dye is dyed in succession in each solution.

In order to achieve the overall objectives of this project, giving a large scale view of the dyeing processes, a visit to a textile factory was done.

A visit to the Textile Museum Cairo was organized for better understanding the historical perspective of industrial systems.

Overall, the experimental work wholly developed in this project was focused on three historically relevant steps in the dyeing process: The natural product extraction obtained from the real ancient dyes used in the regional embroidery; the analysis of dyes with prescriptions as a foundation of the history of dying industry; the synthesis of new dyes in the form of synthetic process and great environmental control perspective.