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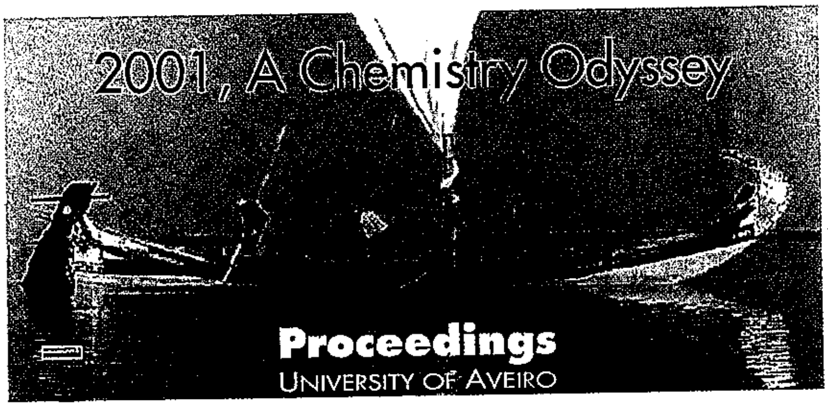

History of Chemistry as a strategy in Teacher Education

Maria de Fátima Paixão e António F. Cachapuz
Escola Superior de Educação. Instituto Politécnico de Castelo Branco. Portugal
fatimapaixao@ese.ipcb.pt
Departamento Didáctica e Tecnologia Educativa. Universidade de Aveiro Portugal
cachapuz@dte.ua.pt

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; Níaz & 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 aspects 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.

Epistemological Categories	Analysis Dimensions	Teaching Practice Indicators (examples)
I – Scientific methodology	A – Methodological pluralism	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).
	B – Theory / observation / experiment relations	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
II – The dynamics of scientific knowledge construction	C – Scientific discovery: Context and structure	Activities exploring historical controversies in the establishment of a respected scientific theory (i.e. texts and related questions)
	D – Error /truth dynamics	Intentional valuation and exploration of students' errors. Identification of misconceptions. Discussion of discrepant Experimental Work results.
III – The human and social side of science	E – Images of scientists and the scientific community	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.
	F – STS interrelations	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.

Figure1 - 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.

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	Scientific Methodology		Dynamics of Scientific knowledge construction		The Human Side of and Social Science	
	Before	After	Before	After	Before	After
Teacher A	-Linearity of ways of work beginning with observation/experiment -Absence of problematizing questions - Descriptive report organised in a closed manner	**- 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.	- Valorisation of definitions and factual knowledge of science. - Static and cumulative knowledge, without structure for discovery and a-historic. - The aim is always to obtain "correct answers". – Non-perception of pupils' misconceptions. - Position of simple realism.	- The importance of the HS is highlighted and the process of scientific knowledge building is valorised. The resources used are justified in parallel with HS - Lack of a certain social, economic, 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.	- Excessive valorisation of scientists; Pupills are incentivated to follow scientific careers. - The importance of communicating results but far from discussion and controversy. - An image of chemists "mixing substances". - Frequent examples of the relationship between chemistry and the environment but from an illustrative perspective.	- Discussion between pupils is compared with the controversy which arose in Lavoisier's time. - References to scientists people and to the scientific communities. - Reference to the social value of scientific knowledge and the need for public recognition of that knowledge. - STS interrelations are highlighted in the ambit of establishing the theory of oxygen and in the current implications.

Teacher B	- Rigid way of working (EW), methodological dogmatism; non-reference to aspects of the methodology of research. - Importance given to the rule, inductivistic positions in a course of action which goes from the particular to the generalisation. - Insistant use of the verb "to see". - Valorisation of observation independent of the theory.	- Abundant variety of proposed tasks and complementary activities. - In WE processes and courses of action are clarified Reports from a critical perspective. - References to aspects of current research and historical contexts. - The subject matter is not treated in a linear way. - The need for scientific theories for interpreting phenomena is highlighted.	- Non-contextualization of the theories presented. Isolated reference to HS, in the ambit of atomic models, with illustrative paper. - The course of scientific knowledge building is ignored. - A dogmatic understanding of scientific knowledge is pointed to. - "Incorrect" answers are ignored. - There are no acts of prediction or questioning.	- The importance of HS is highlighted and the course of scientific knowledge building is valorised. Many biographical and contextual aspects are introduced - The temporary validity of a theory is highlighted. - The pupils' misconceptions which arise in the lesson are identified. Error is considered a normal part of scientific progress. - Movement away from the perspective of simple realism.	- No reference is made to scientists or to a scientific community and its work - Image of acquired knowledge which is aproblematical, definitive, with no human or social side. - Non-exploitation of the theme in a STS context. The Science and Technology implications in environmental and political questions and vice-versa are not shown.	- 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.

Figure 2 – Evolution in the teaching practice of the teachers

“Radiation and Environment” a regional theme for the improvement of the Scientific Culture of a School Community

Alina Louro [1] and Maria de Fátima Paixão [2]

[1] Escola Secundária Afonso de Albuquerque, Guarda, Portugal.
[2] Escola Superior de Educação, Instituto Politécnico Castelo Branco, Portugal.
E-mail: fatimapaixao@ese.ipcb.pt

Introduction

Fig. 1 School Science Community

Fig. 2 Exploration of the radioactive materials

Research Questions

According to the presented aspects we considered important to investigate:

1) Which images of Science, scientific knowledge development and STS connections, do the students of a school community present at the end of compulsory school? What's the connection between those images and the perspectives of the New Philosophy of Science?
2) What kind of images about the Nature of Science, the development of the scientific knowledge and STS connections do teachers of that School Community present?
3) Do teachers of scientific and technological subjects have very different images about Science, scientific knowledge development and STS connections from those of Humanities?
4) Do teachers and students have very different images as far as Science, scientific knowledge development and STS connections are concerned?
5) In the 20th century, in a region with a high level of radioactivity and uranium exploration as Guarda, what's the teachers' and students' level of scientific culture on this topic area, accounting that both belong to a school community of this region?
6) How do teachers, namely Physics and Chemistry teachers, value the "Radiation and Environment" topic area as a stimulus for the development of students' scientific culture?

Methodology

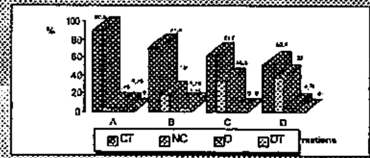
The Research[3] has followed a Case Study Research methodology. The analysed data were obtained through questionnaires given to teachers (n=136) of several subjects divided into two areas, and to students (n=136) at the end of compulsory school, as well as through interviews to Physics and Chemistry teachers.

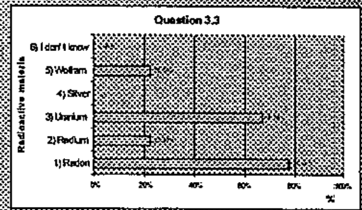
The 9th grade students' option was linked with two order of reasons: the students have already some perspectives on the basic compulsory education– present– and some expectations of the secondary one – future. This is an important step on students' schooling, it gives the citizen a general education which will lead to different areas of study in a vocational sense.

The first part of the questionnaires regards general aspects of Science and scientific knowledge, science methodology, knowledge development and also the Science, Technology and Society relation. The second part focused on aspects apparently related to the previous ones now included in the topic area of *Radiations*. The questions were validated independently by two specialists and some slight changes were introduced after an Pre-Study.

In order to go through the results of the Investigation and to inquire its impact and interest it became important to listen some of the teachers who have participated in the Investigation and also about the Results of the questionnaire itself. The interviews aimed to reflect upon the Curriculum and the importance of treating the topic area *Radiations* in the region of Guarda where it is found the studied school community and also about the Results of the questionnaire itself.

From the results to the general conclusions and the implications





An Experimental Work Project with STS Orientation: Dyes and Dyeing in a Regional Context

Maria de Fátima Paixão, Marieta M. Pereira, António F. Cachapuz

Introduction

Castelo Branco is a small town in inland Portugal with a unique kind of embroidery of eastern inspiration. Dyed silk thread of different colours is used to embroider onto linen, and motifs, colours and techniques used make it easily identifiable. Today, these embroidery is 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, in which dye-works were an important feature. Although for a long time, the silk thread was dyed with natural dyes obtained from plants and animals such as onion skin, madder, green walnut shell, purple and yellow lilies, cochineal... 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 (Ciência Viva /Living Science) with students from several lower and upper Secondary Schools of the Castelo Branco region.

Objectives

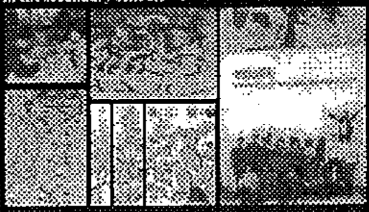
* To develop a better understanding of the Chemistry involved in the dyeing process including the use of laboratory techniques of analysis and synthesis and how to extract dyes from the natural products and to synthesise chemical dyes.
* To identify some of the colours used in the embroidery from extracted and/or synthetic dyes.
* To reckon the embroidery of Castelo Branco as a cultural and historical heritage with economic potential, associated with a handicraft 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 dyes "mimic" perfectly the colours and tonalities of the embroideries from the XVII and XVIII centuries. It is very interesting to isolate the dyes and do the corresponding analysis.
* We get a better understanding linking all these aspects.
* This work was very important for us; it was not just the academic topics but essentially their integration with cultural and social roots.

Developed Project Activities

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



Work group: Search on plants traditionally used for dyeing silk of the embroidery.
- They plucked plants and flowers; after characterisation they presented Posters in the classroom.

Dyeing silk with alizarin-mordants[1]

a) The silk is immersed in water with 1% of ammonia and few drops of detergent.

b) The students prepare mordant solutions of $SnCl_2$, $FeSO_4$, $CuCl_2$, $K_2Cr_2O_7$ and $Al_2(SO_4)_3$

c) The silk is introduced in each mordant solution and heated until 80°C.

d) The alizarin is dissolved in water and gently warmed (30°C).

d) The silk and the mordant solution is than added to the pink-alizarin solution.

Beautiful green, red, orange, brown and blue colours have been obtained.

In the Coimbra Chemistry Research Centre the students had the opportunity to visit a modern Organomettalic Synthesis laboratory were they had the opportunity to realise a set of more elaborated synthesis, like the synthesis of Alizarin using high pressure equipment. They also used the v-uv spectroscopy to analyse dye samples previously prepared in their schools. They could associate these techniques of analysis with the detection of contamination of Industrial effluents in an environmental control perspective.

Selected Examples From the Experimental Activities

Natural products extraction

Onion skin dye - The pigment is from the flavone family with the trivial name quercetine and it can easily be extracted by boiling the onion skin in water.
In the second part of the work the silk is dyed by direct immersion in the dye solution.

Synthesis of Azo Dyes[2]

a) 4-nitroaniline is dissolved in concentrated HCl

b) A water solution of sodium nitrite is addeddropwise to the amine solution at 0°C; this gives the diazonium salt solution.

c) The diazonium chloride salt is than added to a sodium hydroxide solution of fenol, 1-naftol and 2-naftol. Beautiful colours, violet, orange and yellow are obtained.

d) The silk is dyed by immersion 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- Covilhã, was organized for better understanding the historical perspective of industrial dyeing.

Otherwise, the experimental work globally developed in this project was focused on three historically relevant steps in the dyeing processes:
The natural product extraction selected from the real ancient dyes used in the regional embroidery; the selection of alizarin with mordants as a landmark in the history of dyeing industry; the synthesis of azodyes due to their easy synthetic process and great actual industrial impact.