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Challenges on Science Teacher Education for the new century: an approach based on the epistemology of curricular themes

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Abstract: In a model of technical rationality, theory commands practice. Going beyond that model, suggests that knowledge needs a context and cannot be based only on supposed criteria of universal objectivity. In relation to Teacher Education, many general new orientations have emerged but there is still no didactic intention, which results in effective change in the classroom. The new orientation implies the need to question the simplicity of the images of the science we teach and this means, concerning teacher education the need for a way that improves the suitability of teaching practices, while at the same time enabling teachers to develop both personally and professionally. It is necessary to engage in the research process and to make it centralised in the classroom. The guided decisions to an understanding of the nature of the science demand a real understanding of the History and Philosophy of Science. Starting with the analysis of the basic proposals of the recent Portuguese curricular reform, which is in a phase of declining enthusiasm due to the ineffectiveness of the changes in teaching classrooms, the study has been put into the framework of the New Philosophy of Science. The main hypothesis of the study was that, to carry out Teacher Education, exploring action-research perspectives, guiding teachers towards a critical and epistemologically based perspective, particularly starting with the analysis of their usual teaching and leading them to an epistemological reflection on the subjects (to use a concrete theme and to discuss with them their epistemology), results in a substantial improvement of their teaching practices and, in particular, in their professional fulfilment. The methodological strategy outlined is organised in three interrelated phases: One naturalistic phase, where over 40 hours of teaching were videorecording and analysed. We focused on the theme "mass conservation in chemical reactions", because it is a

relevant historical and cultural theme, which may contribute to the creation of more consistent images of science, and it implies that the teachers focus on the necessity to consider multiple interrelated aspects. The second phase considers the development of an in-service Teacher Education Program, exploring the action-research perspective, with the elaboration of a teaching plan with new didactic materials. The third phase considers the implementation of the new developed plan by two cooperative teachers whose teaching practice was recorded earlier. This phase compares the analysis of the new proposals with the initial phase.

We present and discuss some aspects of the teacher education program and the analysis made by participants during and after the participation in the designed program and the implications we point out for a new model of science teacher education using the curricular themes in an action-research perspective.

INTRODUCTION

Educational innovation can only really succeed if it also results in a means of professional development and teacher empowerment – this implies Teacher Education which will have an effect on the way that education is carried out and also, on the way it is experienced by the teacher.

We now have some new general orientations for guided teacher education (Schon 1987; Zeichner 1993) and what is still missing are systemic research approaches to teacher education in order to improve teachers' personal and professional growth. Teachers need to reflect more and better on their own actions and this will have a positive influence on their future classroom strategies. We need educational research strategies that will help classroom teachers to promote effective and conscious changes in their teaching.

The more consensual position indicates that each teacher conceives and orients his/her teaching practice depending on his/her conception of the nature of science and scientific knowledge, but also depending on his/her experience, his/her interpretation of curriculum, on the way he/she conceives education and his/her whole institutional vision, and, in particular, depending on the way he/she conceives his/her professional status and the more general goals of science education.

As Gallagher (1991) said, "secondary teachers' knowledge about the nature of science is important because they play a key role in forming the image of science that is held by the general public", and he asks "what do teachers understand about the nature of science, and how does this knowledge influence their teaching?"

Many research studies point to a strong link between teachers' conceptions and their practices (Pomeroy 1993; Lederman 1986), others consider some influences and a selected collection of situational variables (Brichouse & Bodner 1992; Lederman 1992).

Among teachers' images of science, some prevail over others, namely positivists', empiricists' and inductivists' perspectives (Aguirre 1990; Hodson 1985, 1993; Praia 1995; Praia & Cachapuz 1994, 1998) and science is viewed exclusively as a definitive well-established body of knowledge. The understanding of scientific principles and relationships received far less attention than terminology; teachers devoted no time to the discussion of matters related to the nature of science, such as how the knowledge included in the curriculum was formulated or the process by which scientists validate knowledge, teachers emphasised the objectivity of scientific knowledge and they based

the objective aspect on scientists' use of the scientific method; teachers frequently fail to point out obvious connections between classwork and the world outside the school (Gallagher 1991).

Gallagher (1991) and Matthews (1990) attribute responsibility for this to the fact that teachers have had no formal education in the history, philosophy and sociology of science.

Despite some well known dissimilarities between contemporary epistemologies about scientific construction and its structure, scientific philosophers, particularly Khun, Lakatos, Toulmin or even Feyerabend, converge on a coherent image of science with important implications for Science Education (Cleminson 1990, Duschl & Guitomer 1991, Hodson 1985, 1992, 1996, Gil-Pérez 1996, Duschl 1995...). These arguments known as New Philosophy of Science (NPS) may be summed up in the following way: 1- Scientific knowledge cannot suggest an absolute truth, it has temporary status and errors must be an object of reflection; 2- Scientific discoveries have context and structure and the History of Science helps us to understand those aspects; 3- Scientists are part of the very world they investigate and they must constantly submit their results to the certification of a scientific community; 4- There is no unique and singular method of producing scientific knowledge but a context-dependent methodological pluralism; 5- Observation does not exist apart from a theory that orientates and gives meaning to it. Scientific theories interpret and explain the world tentatively; and 6- Science is not objective, impersonal and problem-free, but it is closely related to society and technology.

We know that the history and philosophy of science has for many years been absent both from science curricula and, in particular, from science teacher education (Matthews 1990, Acevedo Díaz 1996, Pomeroy 1993...). During the 80's and early 90's the consideration of the inclusion of philosophical aspects in science teaching education began to increase and relate the philosophy of science to science teaching and learning.

From another point of view, as we mentioned earlier, educational research, in practice, has not achieved classroom practice changing proposals. Teaching practice is mainly guided by pedagogical preoccupation and the images of science and scientific knowledge in the classroom do not tally with the framework of the NPS principles. These ideas led us to the problem of which good and innovative strategies of Teacher Education should be considered in order to promote effective changes in teachers' usual classroom practices.

Consequently, a major challenge now is how to strongly consider effective science teacher education in that perspective: Teachers need to understand the importance of the inclusion of the philosophy of science in their science teaching. There are two aspects related to the NPS. They are the consideration of the social construction of science and scientific knowledge and the necessarily associated technological development (critical STS perspectives (Matthews 1994)) and the importance (and indispensability) of the inclusion of the history of science in science teaching. These aspects prevent some underestimations about the public and social image of science... and they help teachers and their students to gain an adequate understanding of the nature of science and its construction.

A possible way of doing this is to improve conditions which will enable teachers to analyse their usual teaching after an guided reflection on a previously selected theme of

the usual Curricular Programme. This suggests and implies as a possible solution involving teachers in cooperative action research studies designed in order to conceive and explore concrete curricular strategies based on the History and Philosophy of Science (Monk & Osborne 1997) and also to analyse and discuss the way they may implement them in the classroom.

Mass conservation in chemical reactions: an epistemologically relevant theme

In our study (Paixão 1999) "mass conservation in chemical reactions" was selected as a relevant theme because it has usually been viewed from a poor perspective and because of this, it has been a point of crystallisation of an exclusivist form of academic knowledge; students only resolve "exercises" (non problematic questions) of equation balancing and stoichiometric aspects, and even when they do them, it does not follow that they understand what they have done.

Classroom practices and textbooks have a particular incidence of an empiricist point of view (as far as this theme is concerned) which implies the absence of a current perspective on the contemporary principles of the New Philosophy of Science (NPS).

With the same guiding principles, Experimental Work (EW) developed in classrooms (practical work) is very far from those principles. Frequently, work proposed on the theme referred to above is according to a confirmatory epistemological perspective involving, generally, the 'classical' chemical reaction of precipitation of the lead iodide by reaction between potassium iodide and lead nitrate.

On the other hand, we must consider the academic interest of the theme: it is the prerequisite for all and subsequent understanding of chemistry and it has a central position in the curricular program of basic studies.

From a scientific point of view, the understanding of the mass conservation principle, and also the understanding and knowledge of the general theory of chemical reactions, is indispensable for the understanding of the whole structure of the science of properties and the transformation of substances. There are many research studies that point out the existence of students alternative conceptions about this theme (Hesse & Anderson 1992, Yaroch 1985, Ben-Zvi et al. 1987...)

From the epistemological point of view already referred to earlier, the study of the controversies that followed the interpretation of one of the most common chemical reactions, i.e. combustion, and the establishment of the general theory of chemical reactions, the mass conservation principle (later an empirical law), which guided Lavoisier in the establishment of his theory, cannot be underestimated. It is also a historically and culturally strong theme due to the correspondence of a period in the history of mankind and in the history of science with many special important social, economical, political and scientific implications. After the commemoration of the 200 years since Lavoisier's death, the available literature about that period of chemical history increases quantitatively and qualitatively (Bensaude Vincent & Stengers 1996...). The theme is also important in a social and technologically up-to-date and foreseen future context – thermal power stations; incineration; recycling...

Teachers cannot ignore all those questions about the way scientific knowledge grows, and they must give students an image of that difficult and contextualized construction.

There are, in fact, many epistemological elements that contribute to a more consistent

image of science, like scientific controversy, scientific community and societies, technologies associated with science, publications, communications and scientific correspondence... acceptance or non acceptance of a new theory... social, economical and political implications which, as was the case in a period such as the French Revolution, influenced the status of chemistry as a modern science. That is a non-neutral view of science very different from the common image transmitted by teachers in science classrooms.

HYPOTHESIS AND AIMS OF THE STUDY

The hypothesis that guided the study was that it is possible to develop in-service teacher education strategies in order to promote teachers' professional and personal growth, using the History and Philosophy of Science (HPS) framework in the teaching of science curriculum themes. This, in turn, results in a substantial empowerment in professional fulfilment and in the suitable images of science transmitted to the students. The presupposition is that this way increases students' learning in the same desirable way.

The aim of the study was to develop a Teacher Education Program (TEP) in order to improve the epistemological perspectives of teachers using, in this case, the theme "mass conservation in chemical reactions" from the curricular program of (low) secondary school, using the HPS framework.

METHODOLOGY AND PROCEDURES

The study was developed in three main related phases.

Four in-service Physics and Chemistry teachers, all of whom were female, participated in the study during the first phase. The participants were permanent members of the staff of four different Portuguese (low) Secondary Schools. The academic background and the professional experience of the participants were diversified.

The general purpose of the first phase of the investigation was to elucidate the epistemological perspectives in teachers' practices. Beyond this general purpose, the effective value of that first phase in the whole study, was to elucidate the main difficulties which teachers face in their practices and to give us some orientations for the elaboration of new teaching strategies and mainly to give us some materials for using in the individual teacher education phase. These materials give the collaborating teachers the opportunity to become aware of the necessity of developing the epistemological dimension of the understanding of science teaching and learning and to allow them to assess the evolution of their usual practice. These aspects give them the required awareness of progress made and the differences between the images of science and scientific knowledge held before and after the participation in subsequent phases of the study. With these objectives the study was conducted according to a naturalistic approach. We videorecorded over 40 hours of actual teaching, on the selected theme. It was our intention to have the same thematic aspect from the beginning. We obtained written protocols and analysed teacher epistemological conceptions (epistemological discourse – oral discourse and proposed teaching activities). It was simultaneously a descriptive and a critical interpretative process of data analysis, with a guiding theoretical framework instrument (Figure 1). This was the instrument of analysis of classroom practice. The question that guided this 1st phase was to investigate what congruence there was between the framework and the classroom practices of teachers.

It must be forgotten that we use an epistemological framework to interpret pedagogical

and didactic situations.

Epistemological Categories	Analysis Dimensions	Teaching Practice Indicators (examples)
I – Scientific Methodology	A – Methodological pluralism	<p>Explicit references to some episodes of the HS and/or current aspects of scientific investigation with relevance to different scientists' working methods.</p> <p>Discussion of students' ways of working with clarification of the means of selecting experimental proceedings and their adequacy and/or limitation (not recipes).</p>
	B – Theory / Observation / Experiment relations	<p>Theoretical considerations before observation and experiments.</p> <p>Initial problematic questions and predictions.</p> <p>Critical report of the Experimental Work guided by problematic questions and including critical assessment of the results</p>
II – The dynamics of Scientific knowledge construction	C – Scientific discovery Context and structure	<p>Activities exploring historical controversies in the establishment of a respected scientific theory.</p> <p>(i.e. texts and related questions)</p>
	D – Error /Truth Dynamics	<p>Intentional evaluation and exploration of students' errors.</p> <p>Identification of misconceptions.</p> <p>Discussion of discrepant Experimental Work results.</p>
III – The human and social side of science	E – Images of scientists and the scientific community	<p>Explicit references to the human side of scientists.</p> <p>Opportunities for the students to express their own ideas and confront them with their colleagues' ideas and/or with the current scientific version.</p>
	F – STS interrelations	<p>To begin with a social or a technological problem.</p> <p>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.</p>

Figure1 - Instrument of teaching practices analysis

At the same time, the teachers involved in the study answered a questionnaire which
<http://www.atee.org/htm/conferences/leipzig/abstracts/rdc2-paixao.html>

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consisted of eight open items related to the epistemological consistence of the teachers' reading of the curricular programme (Paixão & Cachapuz 1998) and it was intended to be used in conjunction with the analysis of teaching practices (Figure 2).

The following items have as their reference document the Official Physics and Chemistry Programme for low secondary school (Ministry of Education, May 1995)

Item 1 – What provision was given, on a central/school/personal level, for aligning your training with teaching practice according to the new Programme?

Item 2 – Do you consider your training adequate for teaching practice according the new Programme? Please refer to any particular obstacles to the effectiveness of the programme guidelines.

Item 3 – Comment on the link between the main goals and the methodological proposals presented in the new Programme.

Item 4 – Point out some aspects related to the "nature of science" as presented in the Programme.

In subsequent items we present some transcriptions taken from the text of the Programme. Please comment on them presenting your own position in relation to those assertions in the context of the Programme.

Item 5 – "Pupils must learn to do careful observations" (p. 17; p. 35). Please comment on this critically.

Item 6 – "It is indispensable that students take advantage of the experimental data" (p. 14). Please comment on this critically.

Item 7 – It is desirable that each thematic area be developed around a central question and with attention to the existence of real world context where the scientific knowledge acquires relevance" (p. 36). Please comment on this critically.

Final Item - If you want to make any comments, suggestions, etc., namely about any aspects you consider missing, related to the whole Programme, please write them down.

Figure 2 – Items of the Questionnaire.

During the second phase the planning began, guided by the following question: What change is possible? And we started the development of the Teacher Education Program (TEP) simultaneously with the preparation of a lot of historical materials that implied texts and related experimental sheets and STS questions. The TEP described above was prepared and began with the organisation of the curricular strategies and materials with the required epistemological discussion. The third phase was the continuing development of the TEP that now includes the teaching of the proposed theme according to the described perspectives and finally the assessment by the participants (teachers and students) involved in the program and the actual teaching practices developed, using half-structured interviews. Only two of the initial four teachers involved

wanted to participate in the formative phases. On the one hand, we initially intended to give individual hard training by involving them in an individual action-research investigation developed in collaboration with the researchers. On the other hand, in fact, only two teachers, in fact, accepted to be involved in this kind of study.

The analysis process of the implemented teaching during the third phase was parallel to the process done in the first phase, using the analysis instrument referred to earlier. Following the analysis and the teachers' confrontation with their developed teaching, researchers conducted the interviews referred to above.

This kind of research is included in a case study methodology in the perspective indicated by Yin (1987, 14): "The case study allows an investigation to retain the holistic and meaningful characteristics of real-life events" and "are the preferred strategy when "how" and "why" questions are being posed". The results from the research are concrete aspects related to each presented case and they can be used to confront them with others in similar contexts and to stimulate continuing research in the same direction. This is more a question of transferability than a question of generalisation.

TEACHER EDUCATION PROGRAM

Given the nature of the study (collaborative action research (Elliot 1994)) we could not separate the methodology and the effective development of the study – The design and implementation of the Teacher Education Program (TEP).

The Teacher Education Programme (Figure 3) involved seminars, discussions and reflections with the collaborative organisation of the strategy and the preparation of materials. This phase included the discussion of the teaching recorded earlier and the differences made by the new co-operatively designed teaching proposals.

Meeting	Date	Place	Time	Aims and activities
Seminar	23 April 1997	The University of Aveiro	8 hours	<p>. To present and discuss the interest of SH and EW as relevant dimensions to innovative science teaching strategies (Prof. J. Praia – University of Oporto)</p> <p>To critically explore a teaching proposal using the theme: "mass conservation in chemical reactions" at low secondary school levels (M.F. Paixão)</p> <p>. To select participants for the subsequent phases of the study (criteria: volunteers; interested in their own education and enthusiasts; having the 8th degree (EB) in 1997/98; and who allow the videorecording of their classroom teaching).</p> <p>An assessment of the seminar was made by the participants (11 part.)</p>

<p>1st Individual meeting</p>	<p>Oct/Nov 1997</p>	<p>The Secondary School of each teacher involved</p>	<p>3/4 hours</p>	<ul style="list-style-type: none"> . Formal contact with the head of the school . To inform about the specific aims of the program. . To make each one aware of the great necessity for involving teachers in their own education with the intention of developing their own teaching practices and the subsequent empowerment of students' images of science (Action-research perspective). . To discuss the importance of epistemologically based science teaching, where the HS and EW as scientific work perspectives are fundamental elements. . To present the selected theme and its educational interest as a whole.. . To give out some documents about Philosophy of Science and Science Education as homework. . To give out to those involved a document organised by researchers concerning the historical and scientific aspects of the selected theme.
<p>2nd individual meeting</p>	<p>Nov 1997</p>	<p>The Secondary school of each participant teacher /Teacher Training College C.Branco</p>	<p>3/4 hours</p>	<ul style="list-style-type: none"> . To critically analyse and discuss the documents given out in the last meeting.. . To discuss the general aspects of science teaching planning. . To discuss the scientific concepts involved and the students' common misconceptions. . To analyse the official Programme and theme insertion. . To discuss the epistemological value of the theme.
<p>3rd individual meeting</p>	<p>Nov 1997</p>	<p>//</p>	<p>3/4 hours</p>	<ul style="list-style-type: none"> . To analyse and discuss the teaching done during the 1st phase (videorecorded and analysed by the researchers) . To begin the planning of teaching strategies
				<ul style="list-style-type: none"> . To prepare materials: to translate

4th Individual meeting	Nov/Dec 1997	//	3/4 hours	<p>texts from the original papers of Lavoisier; to prepare experimental work sheets and STS related questions.</p> <ul style="list-style-type: none"> . To discuss the adequacy of some materials for the development of the proposed strategies . To prevent some problematic aspects. . To certify that the teacher feels prepared to do the teaching of the theme in the desirable perspective
5th Individual meeting	Dec/Jan 1997/8	//	3/4 hours	<p>During the teaching of the theme:</p> <ul style="list-style-type: none"> . To watch and analyse some videorecorded classroom teaching with the teacher. . To reflect on the basis of initial goals. . To proceed to make eventual adjustments in the initial teaching planning and/or didactic materials . To prepare a questionnaire and a half structured interview to give to the students at the end of the teaching strategies implementation.
6th individual meeting	Feb/Marc 1998 (at the end of the sequence and after the analysis of the written protocols)	Secondary school of each teacher involved	3/4 hours	<p>After teaching the theme:</p> <p>An analysis and assessment of the course (half structured interviews with each teacher):</p> <ul style="list-style-type: none"> - The importance and interest of the TEP. - An analysis of the teaching strategy developed - The interest and/or difficulties in the strategy implementation . To confront the teacher with students' answers to the questionnaire and interviews. <p>Global conclusion:</p> <p>To confront the teachers' analyses with the researchers' opinions and students' opinions – triangle effect)</p>
TOTAL:	April 97/		32 hours	

7 meetings	March 98			
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Figure 3 – Teacher Education Program

This plan for changing the epistemological views of teachers developed during half an academic year, before the 3rd phase began. During that last phase, the innovative phase, there was the specific aim of reconstructing the teaching practices based on an epistemological reflection on the selected theme and particularly on their professional understanding.

This phase developed in a research perspective of collaborative action-research, with the participant teachers and the researchers working together systematically, with videorecording of all the teaching practice, with systematic feed-back on the evolution of the work, a scientific and epistemological preparation of the theme, a collaborative structuring of laboratory materials, common decisions and finally the evolution and assessment of the developed program. Teachers had access to their videorecorded teaching.

RESULTS

The results are reported according to four separate aspects: The first aspect focuses on the epistemological perspectives of the teachers in the first phase, the second explains and analyses the teachers' opinions about the TEP, the third focuses on the new epistemological aspects of the teachers' practices after and during the participation in the TEP and the final aspect highlights the relation between teachers, researchers and students' opinions.

The selected theme was done in the same way by all the teachers, in geographically distant schools and with different academic backgrounds. They used the same central experiment, the confrontation of mass before and after the reaction between lead nitrate and potassium iodide, and after this they induced the mass conservation law. With a total absence of historical references, they used that problematic-free chemical reaction between lead nitrate and potassium iodide, without reference to the existence of gaseous substances and the mass conservation in those cases. There was no discussion of and no reference to Lavoisier's time, life or work, no references to the scientific controversy that accompanied the establishment of the theory of oxygen, no references to the political, social or technological context of the building of scientific knowledge... No mention was made of particular scientific facts, terms or experiments... There was only the image of science as a neutral body of knowledge translating a naive image of realism. Any particular epistemological aspect of the theme was totally absent.

The analysis made of the Questionnaire reveals some difficulty in a sustainable reading of the curricular programmes. Pedagogical and scientific preoccupations prevail and an instrumental view dominates the preoccupations with the whole epistemological dimension which is not taken into account by teachers in the reading of the official programmatic documents. Independently of the epistemological position/perspective presented in each answer, not coherent as a whole, we can point out great difficulty in "interpreting the program".

Concerning the teaching practices developed by the two participant teachers during the TEP we can consider that each one developed the proposed strategies in her own way, as was desirable, but we can conclude that some aspects of epistemological relevance

were considered in the teaching of the theme.

More value was given to a more rationalist image of the role of the experiment and also to the theory and prediction results. The experimental work was developed in another critical perspective, and error was considered to play an important role. The HS conducted the strategy and the dependence on scientific knowledge of the whole context and the related STS questions about the theme were highlighted. The naive realistic perspective about the world was abandoned.

The teachers recognised the difference between their usual teaching strategies and the new developed approach and the great influence of the TEP in changing their science images and their understanding of the teaching and the value of epistemological support for science teaching.

After this guided program teachers can implement the new designed strategies with new materials, using the historical contexts of the theme and improving innovative experimental work in the described epistemological perspective.

The teachers' confrontation with their initial own teaching is fundamental in order to convey to them the need to be aware of the kind of improvements needed. That implies an individual approach to the "intervention phase". In fact different ways of approaching this phase were developed by the authors with each of the two teachers involved.

The teachers' opinions existed in three main related directions: The personal and professional meaning of the involvement in the developed program; the thrust of the program in their classroom practices and the analysis of their own classroom teaching recording and the access to the analysis made by the researchers.

As teacher A said: *"I really want to change... and... I will at least... change the... way... I teach this theme..."*

"The documents were interesting, it was a very good proposal... but what I considered the best during the training was effectively the dialogue between us... I felt the necessity to say and do more in the classroom... students did ask those predicted questions... I could foresee those questions... and... it was interesting."

Having access to the analysis made by researchers was considered a very important aspect: *"You referred to many aspects... I felt these things and... in a concrete way! So, I'm going... to make my teaching practice different... based on the analysis made... I'm going... to improve, no doubt about it!"*

Teacher B evaluated her participation in the TEP: *"It was very useful... all teachers should have access to some videorecorded teaching practice and reflect on them... I think they should."* And about changing her epistemological perspective *"...the experimental method... We used to say that sequence of... of phases... and now I have began to wonder also about this sequence, the meaning of what I used to say."*

The study was developed with the presupposition that to improve teaching, based on an up-to-date epistemological perspective, the students' understanding about the scientific content and their images of science will increase in the same direction as well as the interest and participation in the classroom activities. The students' opinions existed in two directions: their understanding of the curricular theme was really good and the interest in the way it was developed in the classroom was greatly appreciated. The first

aspect was assessed by each teacher and in the interviews conducted by researchers by means of two different questions related to mass conservation in different situations (open and closed system) as well as the interest and participation in the classroom activities. As one of teacher A's students said: *"It was a very different way of learning... It was not just arriving in the classroom and to saying what the subject was."* and he understood that for Lavoisier *"it was not easy for him to arrive at that theory"*. Teacher B's students perceived the difficulty in changing a theory: *"It was difficult... and it took a long time for it to be accepted"*. Concerning the interest of the theme and the way it was done in the classroom he expounded: *"We were interested in what was going on in the classroom... some times this does not happen"*. Another student added: *"We also talked about these aspects outside the school, during breaks or after the chemistry class and... in fact... we talked and... we discussed those problems"*.

All the opinions converge with that of the researchers, in a triangular form of internal assessment of the study, towards the acknowledgement of the interest of this new approach.

CONCLUSIONS AND EDUCATIONAL IMPLICATIONS OF THE STUDY FOR SCIENCE TEACHER EDUCATION

This approach represents a significant improvement which is superior to similar conducted investigations because it involves researchers and collaborative teachers with the same goals involved together with the central objective of effectively changing science teaching practices. Significant efforts have been made to make participant teachers aware of the effective significance of the consideration of the epistemological perspectives in teaching practices with a view to developing students' desired understanding of science and scientific knowledge (images of science).

At present we can delineate a central framework for in-service teacher education: The History and Philosophy of Science contribute in a sustainable way to teacher education. Effectively, when teachers are involved in an action-research program designed with reference to a suitable selected central theme of the curricular programme their classroom practice improves in a desirable, epistemologically consistent way. The images they can transmit to students develop in the same way... It is necessary to start with the selection of an interesting theme, namely with epistemological relevance, and to prepare it, in a concrete way, with really interested teachers. The comparison with usual teaching (self-observation) reveals a good teacher education strategy which increases personal and professional fulfilment. The approaches outlined here may be developed in other epistemologically interesting curricular areas.

There are some critical aspects, as pointed out earlier, related to difficulty in conducting those lengthy studies... In this case the investigation status of the study implies that it should be conducted with only a few teachers due to the individual involvement need of each teacher. But the teachers' conscious adherence to these processes of education is still very weak. There are many challenges in Science Teacher Education but the very well-known resistance to change on the part of teachers is effectively greater. The conscious involvement of teachers is a slow process but it is the only way we now consider effective in changing science teachers' images of science and scientific knowledge, and consequently, which is capable of changing students' images in the same desirable way.

REFERENCES

Acevedo Díaz, J.A. (1996). La tecnología en las relaciones CTS. Una aproximación al tema. *Enseñanza de las Ciencias*, 14, 1, 35-44.

Aguirre, J.A. (1990). Student-teachers' conceptions of science, teaching and learning: a case study in preservice science education. *International Journal of Science Education*, 12, 4, 381-390.

Ben-Zvi, R.; Eylon, B. & Silberstein, J. (1987). Students' visualisation of a chemical reaction. *Education in Chemistry*, 24, 117-120.

Bensaude-Vincent, B. & Stengers, I. (1996). *História da Química*. Lisboa: Instituto Piaget.

Brickhouse, N.W. & Bodner, G.M. (1992). The beginning science teachers: narratives of convictions and constraints. *Journal of Research in Science Teaching*, 29, 5, 471-485.

Cleminson, A. (1990). Establishing an epistemological base for science teaching in the light of contemporary notions of the nature of science and how children learn science. *Journal of Research in Science Teaching*, 27, 5, 429-445.

Duschl, R.A. & Guitomer, D.H. (1991). Epistemological perspectives on conceptual change: implications for educational practice. *Journal of Research in Science Teaching*, 28, 9, 839-858.

Elliot, J. (1994). *La investigación-acción en educación*. Madrid: Morata.

Gallagher, J.J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education*, 75, 1, 121-133.

Gil-Pérez, D. (1996). New trends in science education. *International Journal of Science Education*, 18, 8, 889-901.

Hesse, J.J. & Anderson, C.W. (1992). Students' conceptions of chemical change. *Journal of Research in Science Teaching*, 29, 3, 277-299.

Hodson, D. (1985). Philosophy of science, science and science education. *Studies in Science Education*, 12, 25-57.

Hodson, D. (1992). Redefining and reorienting practical work in school science. *The School Science Review*, 73, 264, 65-77.

Hodson, D. (1993). Philosophic science of secondary school science teachers, curriculum experiences and children' understanding of science: some preliminary findings. *Interchange*, 24, 1/2, 41-52.

Hodson, D. (1996). Practical work in school science: exploring some directions for change. *International Journal of Science Education*, 18, 7, 755-760.

Lederman, N.G. (1986). Relating teaching behaviour and classroom climate to change in students' conceptions of nature of science. *Science Education*, 70, 1, 3-19.

Lederman, N.G. (1992). Students' and teachers' conceptions of the nature of science: a review of the research. *Journal of Research in Science Teaching*, 29, 4, 331-359.

Matthews, M.R. (1994). Discontent with constructivism. *Studies in Science Education*, 23, 165-172.

Matthews, M.R. (1990). History, philosophy and science teaching. What can be done in an undergraduate course? *Studies in Philosophy and Education*, 10, 1, 93-97.

Monk, M. & Osborne, J. (1997). Placing the history and philosophy of science on the curriculum: a model for the development of pedagogy. *Science Education*, 81, 4, 405-423.

Paixão, M.F. (1999). *Da construção do conhecimento didático na formação de professores de ciências. Conservação da massa nas reações químicas: Estudo de índole epistemológica*. Dissertação de Doutoramento, não publicada. Aveiro: Universidade de Aveiro.

Paixão, M.F. & Cachapuz, A. (1998). Dimensión epistemológica de los programas de física y química e implicaciones en las prácticas de enseñanza: qué lectura hacen los profesores? In Banet, E & Pro, A. (Coords). *Investigación e innovación en la Enseñanza de las Ciencias*, 284-293.

Pomeroy, D. (1993). Implications of teachers' beliefs about the nature of science: comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education*, 77, 3, 261-278.

Praia, J. & Cachapuz, A. (1994). Un análisis de las concepciones acerca de la naturaleza del conocimiento científico de los profesores portugueses de la enseñanza secundaria. *Enseñanza de las Ciencias*, 12, 3, 350-354.

Praia, J. & Cachapuz, A. (1998). Concepções epistemológicas dos professores portugueses sobre o trabalho experimental. *Revista Portuguesa de Educação*, 11, 1, 71-85.

Praia, J. (1995). *Formação de professores no ensino da Geologia: contributos para uma didáctica fundamentada na epistemologia das ciências. O caso da deriva continental. Volume I*. Dissertação de Doutoramento, não publicada, Aveiro: Universidade de Aveiro.

Schon, D. (1987). *Educating the reflective practitioner*. San Francisco: Jossey Bass.

Yarroch, W.L. (1985). *Student understanding of chemical equation balancing*. *Journal of Research in Science Teaching*. 22, 5, 449-459.

Yin, R.K. (1987). *Case study research. Design and methods*. Beverly Hills: SAGE Publications.

Zeichner, K. (1993). *A formação reflexiva de professores: Ideias e práticas*. Lisboa: Educa.

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