Against a Negative Image of Science: History of Science and the Teaching of Physics and Chemistry

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Abstract. After a first approach to analyze which is today's status of the history of science in high school Physics and Chemistry classes, we attempt to demonstrate that an appropriate introduction of several aspects of History and Sociology of Science in our classes can operate a significant improvement in pupils' image and attitudes in science and science teaching. We will show that several groups of pupils from 15 to 17 can improve significantly their interest in science after at least a year working with papers containing many different activities that involve several historical aspects of science, like context biographies, original papers, reports on STS in history or videos showing the making and growth of major concepts in P&C.

Introduction

Several authors agree that there has been a negative public image of science since the end of the 20th century (Chalmers 1990; Wolpert 1992; and Holton 1996). In fact, even though most of the population (approx. 70%) have a positive vision of science, anti-science feelings are arising in groups with both a higher education level and who have a major impact in mass media. Among those anti-science groups, there are those who these authors refer to as *relativistic science philosophers* according to whom there is no rational way to choose between rival theories, thus science cannot furnish any valuable truth about how the world works. There are also the *strong program sociologists* who think that society not only influences non-cognitive aspects of science (i.e., its own social organization) or 'bad' science (the Lysenko case or the Aryan Nazi science) but also cognitive aspects, 'good' science. They also mention *fundamentalist* (i.e., creationist) or *mystical groups* which have always been opposed to science.

All those groups oppose globalization by means of mass media, where they show a negative vision of science and they consider scientists responsible for the technologies which have contributed to the development of transport, telecommunications, computers, etc. and, finally, for problems related to globalization itself (structural unemployment, increasing inequality between the rich and the poor . . .). There are also some *pacifist* and *ecologist* groups which find science guilty because

of new weapons (nuclear, chemical, biological ...), increasing pollution and extinguishing resources. And finally, certain feminist and ethnic groups coincide in considering science as male chauvinist and partially devoted to Western culture. To sum up, according to Holton (1996), it seems that the formerly protected position of science has turned against it and has promoted it to be taken as a clearly ally of power and all because of its compromise with the Cold War and with the implicit promise of getting immediate profit. However, we ought not to forget that for centuries (Illustration, 19th century, first decades of the 20th) the main defenders of the scientific enterprise have been the progressive groups of society.

There is also scientism, an attitude which considers science as the only real knowledge (or at least the best one) which is based on the topic that scientific method conveys to elaborate objective, neutral and effective knowledge. Consequently this point of view considers that science is the only knowledge able to give an answer to all theoretical questions and practical problems in life, and so it is legitimate and desirable to entrust the management of human affairs to experts. This vision is shared by some scientists and many technocrats which are also minority groups in society but who have a big influence in mass media.

In addition to the negative image of science presented by those groups and the mythical scientism, if we consider the scarce presence of science in mass media (less than 0.5%) and the superficial way in which it appears, alongside a boring science education in secondary level, difficult, with hardly any laboratory work and unrelated with its context in society and environment (Penick & Yager 1986; Matthews 1990; Solbes & Vilches 1997), we will not wonder at secondary pupils losing their interest and leaving scientific matters (physics and chemistry rather than biology) at the first occasion they have (Matthews 1994). Consequently, if the basis of the pyramid diminishes (secondary science students) so will its summit part (the number of bachelors and doctors), and then the number of well trained science teachers, capable of developing courses most attractive to students, will also lower and so on, until the perverse circle reaches its close.

In order to avoid this present-day crisis in science teaching some authors propose the introduction of history of science in science teaching. This line began in the 1950s at Harvard University by Conant (1957) with the study of historical 'cases', based upon the analysis of key processes in the development of science, together with its philosophical and social implications. It continued in the same university with the first edition of Holton's famous book (1952) which established a decisive point in the use of history and philosophy of science in science teaching, and with *The Project Physics Course* (Holton et al., 1970), with the same historical background devoted to senior high school science pupils (16–18 year-old). Schwab's works (1962) about 'research narrative' are also noteworthy. They offer to the pupils actual historical data that could not be obtained in the school laboratory and the description of problematical situations up to which researchers usually face. All these cases deal with an internal history of science.

Other authors propose the use of Science-Technology-Society relations in science teaching (Aikenhead 1988; Solomon & Aikenhead 1994). We think there are a lot of relations between history of science and STS since they deal with two research topics on a wide common ground: external (or social) history of science or, in other words, STS relations along history. As regards to non-common grounds, on one side we find internal history of science and, on the other side, present-day STS topics which do not appear yet in books about external history of science as far as these ones usually restrict their approach to the 1960s because they need a historical outlook.

Furthermore, if we want to avoid a deformed image of science and scientists in pupils (and in the whole society) as it has been characterized before in this and other numerous papers (Gil & Solbes 1993; Solbes & Vilches 1997), it is necessary to integrate the achievements of both trends of research in classroom activities and materials. This item agrees with the idea that the first requirement to teach properly is to have profound knowledge of the topic to be taught, which implies not only its contents, but also the methodological aspects, history of science, STS interactions and recent scientific developments.

For all these reasons, we state that at first it is necessary to analyze the role which the history of science has played in the teaching of Physics and Chemistry (P&C) in the last years of secondary level in Spain. and the consequences which it has produced in our pupils and in their image of science as well as in their attitudes.

Our hypothesis is that historical aspects have been generally ignored in the image of P&C transmitted to pupils and there is a lot of distortion and historical mistakes when history is introduced, even if scarcely. In consequence, students get a deformed image of how scientific concepts are built and grow and so they tend to adopt a negative attitude towards science. And this deformed image of science without historical aspects, no STS and so on is one of the reasons for that negative attitude, although there are many others, like the lack of confidence of pupils' in success after their assessment, the teacher's method of teaching, the absence of laboratory tasks and others, as is shown in several researches (Yager & Penick 1986; Solbes & Vilches 1997). In order to verify this hypothesis, we started with a global analysis of several aspects of history of science as they appear in ordinary textbooks (Solbes & Traver 1996). We have analyzed a wide range of samples including 48 textbooks and covering almost the whole of Spanish publishing companies (Traver 1996), including the most widely extended P&C textbooks for the three higher secondary school levels (15 to 17). The whole of samples included a total of 991 chapters and 19142 pages. We obtained the following results. In a majority of cases, the number of chapters and pages shows rather a testimonial presence of some references to historical aspects but, at the same time, in recent editions we can detect an increasing presence of detailed biographies (16.1% chapters, but only 0.9% pages) including some marginal and anecdotal references. As we expected in advance, the appearance of the historical development of certain concepts is also significant (25.3% chapters, 2.5% pages) but we always found the

same traditional cases: atomic models, historical controversy of light duality, the construction of heat theory or the also common case of the origins of dynamics with Galileo and Newton.

Nevertheless it is important to highlight the scarce presence of materials with some appropriate historical contents, like literal quotations and original papers (12.1% chapters, 0.9% pages). In practically none of the textbooks examined is history of science used as a teaching reference and neither is it used as a possible storyline. We must also notice the scarce appearance of explicit activities or exercises where the use of history of science is a proposal for the classroom or at least as homework for the pupils (14.4% chapters but only 1.1% pages). Almost all the proposals belong to complementary material, at the end of a chapter or section, so we can suppose that the actual use in the classroom is really doubtful, only those pupils more interested to enlarge their knowledge will actually make good use.

Proposal to Introduce History of Science in the Teaching of Physics and Chemistry

In order to go on with our research just before synthesized we have asked ourselves the following questions: Which activities taken from history of science are more suitable to be introduced in the teaching of P&C? Which consequences has the using of history of science in pupils as regards both their image of science and their attitudes towards science?

According to our hypothesis we believe it is suitable to introduce some aspects of history of science in the teaching of P&C, so that pupils can better understand how science works, how it is built and how it develops and which are the social repercussions of scientific achievements. Consequently we think that this historical focus will generate a positive attitude towards scientific knowledge. This attitude will at time improve the atmosphere in our classroom and will increase our pupils' interest in participating in the process of teaching and learning. This way, science could be integrated as an essential part of common human knowledge. Besides we hope this treatment will get a positive assessment by the teachers.

To test this hypothesis we have designed some classroom papers elaborated as programs of activities which conceive the teaching and learning as a research process (Gil et al. 1991), in such a way that the programs include different activities with a historical approach. We have chosen several criteria to present our proposals of programmed activities, which include many aspects of the process such as how scientific knowledge is achieved and improved, but we also include some of the problems which arose during the first stages of the research and which led to the achievement of the most outstanding theories. We are also concerned about the existence of some parallelism between the ideas prevailing in different historical periods and our pupils' first ideas (Hashweh 1986), about the introduction of concepts and the objections and epistemological obstacles that had to be overcome until the new concepts were definitely settled and accepted by the scientific com-

munity. We have included the solution of problems and laboratory work and some important controversies originated along the history of science. And finally, we have proposed papers with texts referring to or taken from the original contributions of men and women, so most of the activities become impregnate of this historical focusing.

However, due to the maintenance or, even worse, the reduction of the time devoted to science teaching in the secondary level, carried out in Spain by recent reforms in curricula, we do not intend to increase the usual contents by adding more historical concepts, as they are already overloaded enough. On the contrary, we rather aim to introduce the contents that must actually be taught by means of a historical storyline, so a historical view will allow us to present some particular features of the topics being exposed to the pupils. Above all, we try to carefully select those aspects of history of science, both internal and external history, which we consider worthy to be properly introduced, in order to offset, if possible, the ideas featuring that negative public image of science we have shown before in this and other papers (Solbes & Traver 1996).

Among the utmost criteria to select historical contents we suggest the following:

(a) A historical approach allows us to extract from the History of Science the most significant problems and propose them to the pupils to be solved by stating some learning situations that allow them, in a certain way, to rebuild the scientific knowledge. Thus, we try to avoid what we think is a mistaken empiricist lay-out, that is to introduce laboratory experiments directly without any reference to neither the historical problems that started them, nor to the consecutive hypothesis proposed to understand and solve them.

(b) HS displays the existence of great crisis in the development and growth of P&C (from Aristotelian-scholastic to classical physics, from classical to modern physics) and even of main changes inside the classical science itself (i.e., from phlogiston to the Lavoisier combustion theory, from caloric to the kinetic theory of heat, from considering light as particles to consider them as waves, from distance action to the field theory ...). With this approach we intend to introduce some ideas non prevailing at present, not only to show the tentative character of science but also because of its likeness with some pupils' pre-conceptions and because they have proved to be important epistemological obstacles to overcome. This approach can help to cause conceptual changes in pupils, so that they comply with major changes in concepts, models and theories of the evolution of science (Gil & Solbes 1993).

(c) A historical approach shows the hypothetical, tentative character of science, the limitations of theories, the unsolved problems, etc. This approach presents the adventure of scientific creation to the pupils and avoids dogmatic visions so widely criticized by philosophers and sociologists. We need also to clarify to what extent science is an accumulative matter, for, in a way, most of the worldwide recognized scientific theories have not been completely overthrown but they have been de-

veloped, refined and even generalized, a fact that brings relativism in the selection of theories in question.

(d) HS is essential for pupils to capture the collective and controversial nature of scientific research, originated from the work of very many persons, which is likewise based on the task of more others, in order to avoid the idea of a science basically built by a few geniuses, mostly men, a process based on the contrast of works from different origins whose results converge and show to be coherent (Silverman 1992).

(e) A historical approach provides a proper appraisal of the contribution of women to science, which is commonly ignored and generally undervalued as scientific work, mostly because very often science teaching has been devoted preferentially to certain epochs and certain male clichés (Koblitz 1987; Matthews 1994; Spector 1995). At the same time the role of the contributions made to science from countries which do not have a deeply rooted tradition in scientific research (as our own country may be) is also worth mentioning, although they are commonly unknown for several historical causes. So we can show the obstacles put to the development of science in these countries along history. To sum up, we intend to highlight the role of groups usually discriminated for reasons of sex, country or other motives (Krugly-Smolska 1996) and so make a multicultural approach to science teaching (Matthews 1994).

(f) HS contributes to expound the main problems mortgaging the future of mankind (population growth, pollution, natural resources exhausting, weapon stocks, poverty and its consequences: famine, diseases, etc.). This contribution is possible on the basis of the analysis of some problems which stem from the perverse use of science (like weapons) or arise because of the unwise application of the resources of the Earth, (i.e., what happens with environment pollution). In this respect, science is a necessary condition to solve them, although it is not enough, because we also need the will to get rid of a system in which economical and military interests prevail. Obviously, we cannot solve those problems only with the help of science, but neither can we without it.

(g) HS introduces some examples of the liability of scientists and technicians with social affairs, for instance, the case of Einstein, Born or Pauling reporting the unreasoning use of science during the Cold War, which jeopardized the peace between the nations or, nowadays, the case of many other scientists whose research has demonstrated, despite the opposition of many lobby companies, that radioactivity is dangerous, tobacco and other products cause cancer, CFC damage the ozone layer, CO_2 increases the greenhouse effect, the pollution of the environment by so many substances and processes and so and so on. In a way, most scientists' work is based on clearly human ideals which have been, and will still be, the incentive to solve the aforementioned problems presently, by means of research on alternative energies, non polluting new technologies, public health, the improvement of work conditions and a better quality of life.

(h) A historical approach reveals the contribution of science to the general development of mankind and to a conception of the world based on rationality and critical spirit against any form of fundamentalism (specially against those forms which pretend to have a scientific origin, like social Darwinism, eugenics or racism) or pseudo-science (astrology, UFO beliefs …) and together with the new idea of the Earth as a spacecraft under the control of mankind, who is responsible for the destruction of the ship on which we are traveling.

Research Methods

In order to detect the image of science in pupils and their attitude towards it we have selected pupils at random from the last three years (15, 16 & 17 year-old) in secondary school. These pupils had made a free choice of P&C as a subject, for it is not compulsory in those levels in Spain. Regarding the image of pupils, we have established the results of the control groups (those following a traditional class, with science held by only some superficial aspects of historical content) by means of three questionnaires (named B, C & D) whose main aims will be explained below. The items, short open questions, can be read in the Annex. Questionnaire 'B' is bound to verify if the way in which science grows and the way in which some aspects like social repercussions of scientific achievements and original problems are suitably noticed by pupils. So we hope that this questionnaire will show us up to which extent the pupils' knowledge about scientists and their scientific contributions has been improved. Questionnaire 'C' is intended to show how the pupils perceive some sociological aspects like the evolution of science and the contribution of outmost scientists in Spain. However, we hope that pupils will undergo not only conceptual changes but they will also modify their attitudes in front of scientific knowledge and so they will show a greater interest for learning P&C. That is the reason why questionnaire 'D' will contribute to reveal this change in attitude. In order not to be influenced by the answers of the rest of questionnaires, we have proposed firstly questionnaire 'D' and then we have proposed the other questionnaires B and C, in this order.

These questionnaires were filled under the following conditions. Two different samples stand as control groups ($N = 479$ for questionnaire B, $N = 215$ for C & D). They have been proposed as the resolution of the ensemble of the three questionnaires in a classroom period with enough time to answer the items carefully and during the middle of the last term of the school year. The results obtained appear in the tables entitled as control groups.

So now we will try to verify how it is possible to contribute to the modification of the image of science in our pupils after using, in our P&C classes, these new materials written with a historical approach, taking into account those aspects featured in the last paragraphs by the use of an active methodology. Some of these new materials have been published in part recently (Calatayud et al. 1995–1998), others can be found in Traver (1996).

The experimental assessment of the consequences derived from our hypothesis will be made by means of the analyze of the answers of those pupils who have worked with these materials in the classroom side-by-side during a whole school year with the authors (experimental group 2, containing $N = 116$ pupils) and with four other colleagues who agreed to collaborate in this project (experimental group 1, containing $N = 117$ pupils). After the project was carried out, we compared the results with those taken from pupils who had followed ordinary P&C courses (control groups) to which we referred above in this paper. To compare the changes occurred in pupils in the experimental groups we have used questionnaires B, C and D, already used in the first part of our research (Solbes & Traver 1996). In questionnaires B and D, both experimental groups were melt in one group because we found no significant differences between them, so the sample became $N = 233$. There are not many differences between both groups in questionnaire C, excepting items C4 and C7. These items refer to Spanish science and were probably treated less deeply by some teachers in experimental group 1.

Finally we must show that questionnaires B and C are founded in short open questions dealing with knowledge of facts, people or processes in History of Science, but the questionnaires were proposed at the end of the year and the fact that pupils were able to give the right answers is not merely based in a memorizing learning process, on the contrary we believe that it is because those issues have had a significant positive impact in students' image of science, and this agrees with the better assessment given by the pupils in questionnaire D.

Results of the Research

These are the results we obtained:

1. Pupils who have followed a P&C course with a historical approach, integrated in a model based in science teaching as a classroom research, show an image of science more related to its social context and nearer to reality and, in most cases, show significant differences with those pupils following traditional courses without this approach. We can confirm our hypothesis looking at the following particular issues:

1a. After having undergone a P&C course with a historical approach, pupils who remember some crisis in the evolution of science increases until a 56.7% rate (Table I) and those who are able to answer two or more controversial models reach a 17.9% in experimental group 1 and 32.8% in group 2 (Table II), meanwhile in this very issues pupils who have not followed the course presented respectively the rates of 15.7% (Table I) and 9.3% (Table II).

1b. In experimental groups the knowledge about scientists and their contributions (Table I) improves in such an extent that it reaches a 37.8% of those who can correctly indicate five or more scientists and those who get right the whole of the authors for the works proposed reach a 16.7%, while in control groups these very items where answered correctly by only a 28.8% and a 4.4%, respectively.

Table I. Analysis of questionnaire 'B' about evolution of science and contributions of scientists

Rate of students who:	Control group ($N = 479$)		Experimental group ($N = 233$)		Significant differences	
	%	(sd)	%	(sd)		$\alpha <$
Know about some crisis in the evolution of science (item B1)	15.7	(1.7)	56.7	(3.2)	YES	0.001
Indicate five or more scientists and their main contributions to science (B2)	28.8	(2.1)	37.8	(3.2)	YES	0.02
Indicate properly the whole of the authors proposed (B3)	4.4	(0.9)	16.7	(2.4)	YES	0.001
Know about the social consequences of some scientific works (B4)	52.0	(2.3)	71.6	(3.0)	YES	0.001
Indicate properly which problems were in the origin of scientific achievements (B5)	13.4	(1.6)	40.8	(3.2)	YES	0.001

The knowledge of scientific works made by Spanish authors (Table II) increases from 25.6% in control pupils until 48.3% in one experimental group. The collective nature of science is correctly perceived by a 61.0% and a 71.6% rate according to both experimental groups, meanwhile the control group had only a 35.8%. These results may us affirm that a significant improvement has happened in the perception of a more humanized vision of science by the pupils who have followed the historical approach course. This coincides with the opinions exposed by authors like Matthews (1994).

1c. One can also detect that these pupils understand better some aspects related with scientific concepts in their appropriate context (Table I). For instance, a 58.6% pupils can correctly indicate the social repercussions of at least one to three cases proposed in the items and a 13.0% indicate four or five cases, what amounts to a total 71.6%, against the 52.0% total that control pupils were able to indicate. The rate of pupils knowing problems on the origin of several scientific works also rise (40.8% indicate at least one, against 13.4% in control group). The cases of economic support to science (Table II) are known by among 40.2% and 63.0% pupils in experimental groups, whereas in control group the rate was 26.1%. The relations between science and technology are known by among 58.2% and 68.1% pupils in experimental groups, against 47.9% in control groups. Some facilities given for science development in Spain are indicated by a 14.7% in experimental pupils (4.7% in control ones) and some obstacles are known by 43.1% in one of experimental groups (24.7% in control group).

2. The improvement in pupils' attitudes can be seen in Table III, where we do not separate experimental pupils into groups 1 and 2, as we did before, just because there were no significant differences in their answers. There is an important rate of pupils (64.4%) who give a high valuation to the teaching they have received in P&C (38.3% was the rate in pupils who did not follow the course) and the contribution of the historical approach to this better assessment is valuated by a 82.8% of pupils, a rate that confirms and even goes beyond the good expectations that the control group pupils had (61.3% said that a historical approach would increase the valuation they had made). Pupils in experimental group show a higher interest in knowing more about aspects like the process of science evolution and growing (40.2%), biographies of scientists (24.7%) and the relations STS in history (18.7%), whereas pupils in control group also showed some interest, respectively in those same topics, with rates of 17.0%, 13.9% and 5.3%, which are significantly lower. The grand total rate of answers not showing any interest for history of science has diminished from 44.9% in control group to a significant 12.5% in treated pupils. This quantitative information is completed by the qualitative appreciation (conveyed by means of a detailed observation form) that incorporating activities with historical contents to the P&C course is a factor that contributes to make a good atmosphere of work in the classroom and engages significantly the pupils to increase their participation in the teaching and learning process.

Table II. Analysis of questionnaire 'C' about aspects of history and sociology of science

Rate of students who:	Control group ($N = 215$)		Exper. group 1 ($N = 117$)		Exper. group 2 ($N = 116$)		Significant differences	
	%	(sd)	%	(sd)	%	(sd)		$\alpha <$
Know two or more controversial models (item C1)	9.3	(2.0)	17.9	(3.5)	32.8	(4.4)	Exp. 1 Exp. 2	0.05 0.001
Know some cases of economic support to science (C2)	26.1	(3.0)	40.2	(4.5)	63.0	(4.5)	Exp. 1 Exp. 2	0.01 0.001
Agree that scientific work is a joint action (C3)	35.8	(3.3)	61.0	(4.5)	71.6	(4.2)	YES	0.001
Identify some Spanish scientists (C4)	25.6	(3.0)	28.2	(4.2)	48.3	(4.6)	Exp. 1 Exp. 2	NO 0.001
Know relations between technological progress and scientific progress (C5)	47.9	(3.4)	58.2	(4.6)	68.1	(4.3)	Exp. 1 Exp. 2	0.10 0.001
Know some facilities given to science in Spain (C6)	4.7	(1.4)	12.0	(3.0)	14.7	(3.3)	Exp. 1 Exp. 2	0.05 0.01
Know some obstacles put to science in Spain (C7)	24.7	(2.9)	29.9	(4.2)	43.1	(4.6)	Exp. 1 Exp. 2	NO 0.001

Table III. Analysis of questionnaire ‘D’ about pupils’ interest and attitudes in science

Rate of students who:	Control group ($N = 215$)		Experimental group ($N = 233$)		Significant difference	
	%	(sd)	%	(sd)		$\alpha <$
Give a positive assessment of the teaching in P&C they have received (item D1)	38.3	(3.3)	64.4	(3.1)	YES	0.001
Agree that history of science will increase the assessment they have made (D2)	61.3	(3.3)	82.8	(2.5)	YES	0.001
Would like to learn about the process how science grows (D3a)	17.0	(2.6)	40.2	(3.2)	YES	0.001
Would like to learn more about biographies of scientists (D3b)	13.9	(2.4)	24.7	(2.8)	YES	0.01
Would like to learn more about several aspects of STS in history (D3c)	5.3	(1.5)	18.7	(2.6)	YES	0.001

Conclusions

In the second part of our research we have suggested possible solutions to the problem we dealt with. So we have considered that the lack of interest in pupils and their attitudes of scarce appreciation towards the study of science may be due, in part, to that non historical vision in usual science teaching, a vision that shows a slanting image of the nature and evolution of science. We should then modify that image by means of an accurate presentation of several aspects taken from the History of Science and introduce how scientific knowledge is built, in which historical and social contexts certain theories have appeared and which influences have they had on the social environment itself.

We have verified that it is in fact possible to change pupils' attitudes and increase their interest towards the study of P&C, by means of a slightly detailed treatment of some historical issues, introduced during the process of acquisition of the different scientific concepts and theories, because this is a way to show a more accurate image of science and closer to the actual work of scientists and to the context where it takes place and has taken place along history.

Moreover, we think to have formed pupils who have a more complete image of scientific enterprise, not limited only to its products, its instruments and its methods, but also taking into account the persons, both men and women, who do work in it and its relations to the social and environment context.

We state as a prospect the challenge of starting to change the traditional image of science and, in consequence, the idea that teachers themselves have of the aims of science teaching. Nowadays, wide sections of teachers in secondary levels still think that teaching science is only teaching scientific concepts and, if necessary, some procedures, i.e., a science conceived only for making future scientists and engineers, but not a science that contributes to a general literacy of the ensemble of citizens (Hodson 1994; Matthews 1994; Solbes & Vilches 1997). To sum up, a scientific education that enables citizens to participate, vote or give their own opinions on matters related with science and technology, showing how in the global society, in which science itself is growing up, science and technology play an increasingly main role and avoiding the democratic shortfall of information in decisions on scientific affairs being taken more and more out of their hands.

Annex

Questionnaire 'B' with Open Answers about the Development of Science and the Contribution of Scientists

Item B1. Say briefly some crisis or deep changes in knowledge and theories occurred along history in the development of Physics and Chemistry.

Item B2. Give the names of at least five significant scientists (men or women) and say which was his or her contribution to the development of Physics and Chemistry.

Item B3. Say who are the authors of these contributions to the development of science: (a) law of ideal gases; (b) electromagnetic induction; (c) isolation of radioactive element radium; (d) first model of atom; (e) classic corpuscular model of light.

Item B4. Say briefly which repercussions had in society in its historical moment the following contributions of Physics and Chemistry: (a) heliocentric model of the Universe; (b) electromagnetic induction; (c) nuclear model of the atom; (d) production of new metals; (e) synthesis of the urea.
Item B5. Try to define the problems that originated the following concepts or theories: (a) Lavoisier's theory of combustion; (b) Oersted's experience; (c) identification of radioactive substances; (d) heat and work relation; (e) Bohr's atomic model.

Questionnaire 'C' with Open Answers about Several Aspects of History and Sociology of Science
Item C1. Give two different controversial models or theories used along history to explain some of the following facts that you know: (a) free fall of bodies; (b) planetary motion; (c) influence of forces in motion; (d) heat transfer between bodies; (e) electric phenomena; (f) combustion; (g) nature of light; (h) atomic structure; (i) acids and bases; (j) nature of organic substances . . .
Item C2. Give two examples of the influence of economic support to science along history and nowadays.
Item C3. Do you believe that science and scientific progress are due basically to a joint work or they are rather due to some few scientists? Give a reason or example.
Item C4. Along your school years have you heard about the contributions of Spanish scientists? Which do you remember?
Item C5. Do you know some historical case in which the technological progress (i.e., new devices) have helped the development of scientific knowledge?
Item C6. Do you know the facilities given to scientific work in Spain along history? Give some cases if you know.
Item C7. Do you know the obstacles put to scientific development in Spain along history? Give some cases if you know.

Questionnaire 'D' about Interest and Attitudes Towards Science
Item D1. In a rate from 10 to 0, assess whether the teaching of science that you have been given from former levels until now has increased your interest in science, particularly in P&C, or not.
Item D2. Do you think that using history of science in the P&C class would contribute to increase your valuation? Give some reasons.
Item D3. Which aspects of history of science would you like to know?

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