THE STS INTERACTIONS AND THE TEACHING OF PHYSICS AND CHEMISTRY
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Introduction
In recent years, different lines of investigation have been developed, coinciding with analyzing the causes of the decreasing interest of students towards the study of physics and chemistry, as well as possible solutions. In the same manner, the changes in society and in science-technology, as well as the disconnection between scholastic science and the reality of a scientifically-oriented society, have forced a re- establishment of the objectives in the teaching of science. Both paths have converged in a field that has been fruitful and that is appearing as an effective strategy in science education, as evidenced by the enormous quantity of literature and studies existing in respect to this, as well as the development of numerous projects and studies: related to the treatment of the science, technology and society (STS) interactions in education. The development of the different STS projects attempts to bring the teaching of science closer to the needs of the science student as a member of a society which is more and more technologically developed.

The absence of the STS interactions in the teaching of science
However, what has been stated in theory through didactic investigation in the last decade as a basic component of the science curriculum for improved comprehension of the nature of science and scientific work, in practise in many countries isn't recognised as such and, for one part, a large number of the textbooks fail to cover such aspects,
and for another the teachers aren't only not taking this into account in their teaching, but also have misconceptions about the nature of science and of the STS interactions (Rubba and Harkness, 1993).

As we have already demonstrated in an earlier study (Solbes and Vilches, 1989), through the analysis of 47 science textbooks for 12 and 13-year olds, and physic and chemistry textbooks for 15 to 17-year olds, the percentage of the chapters of said textbooks that included a section, an activity for the student or a paragraph about diverse aspects of the STS relationships was very low (between 4 and 17%). Thus, it can be confirmed that the routine teaching contributes to present an image of science and scientists removed from the real problems of the world, and doesn't take into account the aspects of the STS relationships that mark scientific development. The theories are presented without connection to the problems that they try to solve and related problems and do not take into account science's role in the conception of the world or in the organisation of social problems, thus demonstrating an image of neutral science over the ideologies that ignore serious historic conflicts and which form scientific development. In this way the narrow interactions existing between scientific knowledge and other fields like philosophy, ethics, religion or economy are omitted, without taking into account the social influence in the scientific and technological development, such as the influence of the socially dominant ideas in the selection of the topics of investigation, the commercial priorities in the technological innovation, the sources destined for research and development, and the fact, definitively that science and technology advance in a determined direction influenced by the kind of society in which they're developed, by the institutions that finance them, which supposes a clear conditioning to scientific development.

But the work of the men and women in science, like any other human activity, doesn't take place at the margin of society, of the environment in which they live, and is
logically affected by the historic circumstances of the moment in which it is developed, as well as influenced at the same time in the social and natural environment in which it is immersed. It is difficult to accept that real learning can take place isolated from the real world. However, the idea that science acts as something disconnected from reality (Penick and Yager, 1986) is very widespread in our society, and as we have made clear, also in education.

In order to test this vision of science as it is taught, we surveyed 212 students that take the usual physics and chemistry courses. We found, coinciding with other studies (Schibeci, 1986; Aikenhead, 1987 and 1988; Boyer and Tiberghien, 1989; Ryan, 1990, etc.), that in general the students have a vision of science that is removed from the world in which they live, demonstrate a commonplace image of science, scientists and the means in which they work, are unfamiliar with the mutual relationships between science, technology and the natural and social environments in which they are immersed, and ignore the role played by science throughout the history of humanity, as well as the external influence of scientific knowledge.

All of this contributes to the disinterest of the students towards physics and chemistry and the rejection of such study, as was shown in the study through the negative evaluation that the 212 students made of the instruction received in physics and chemistry, including the disinterested and even negative evaluation labels that physics and chemistry represent for them. This can be understood if we take into account the above-mentioned manner in which education habitually presents this material. However, by recalling the history of science, one realises the passionate characteristics that scientific development has always had which guides the necessity to recover this dimension of the science, the historic aspects, STS relationships, adding to its role of showing a more complete and contextualized image, a potentially motivating factor.
In fact, the students who were interviewed cited many aspects and concrete topics related to the STS interactions in order to include a physics and chemistry course that would be interesting to them, such as concrete applications of both disciplines and the problems that they resolved or raised, the use of new materials and technologies, debates about the current scientific topics, the study of coloring and additive chemistry, topics related to the environment and the problems that development has generated (acid rain, problems in the ozone layer), or activities outside the learning center.

This disinterest on the part of the students was also checked in a questionnaire that we made previously, from another perspective, in which the students were asked to give the reasons for choosing or not choosing physics and chemistry courses, which are optional courses in the last two terms of secondary education. The results indicated (Table I) that when the students choose these disciplines the majority do not do so because they are interested in them, because the study of them seems something appealing or interesting in itself, but rather because they are necessary for further studies that they consider doing and only a fourth of this students declared a theoretical interest in their choice of study.

Not only the absence of the treatment of the STS relationships in the textbooks contributes to the decontextualized vision of science that the students have, but also to this is added the slight importance given by the teaching profession to these aspects in instruction. This was made clear in a study made in order to test the hypothesis according to which we thought that a great part of the teaching profession didn't adequately value the inclusion to the STS interactive aspects in the instruction of
physics and chemistry, and that it could be reflected in different situations, such as their appraisal over the possible causes of the disinterest of the students towards the study of physics and chemistry in the analysis or elaboration that they made in routine materials in instruction.

The teachers and the STS relationships
A high percentage (66.6%) of the teaching profession consulted (103 in-service teachers involved in training and improvement courses) declared that one of the causes of the students' disinterested attitude and, in some cases, rejection of physics and chemistry is the socially-decontextualized image habitually presented of the sciences, that their study is not interesting to the student, indicating the disconnection between what they learn and the world in which they live, the apparent uselessness of what they study, the image of science that is removed from reality without taking into the social implications, without treating the historical aspects in which they are contextualized and without explaining the role of scientists in the evolution of society. Other causes most cited were related to the methodology (82.5%) and in a lower degree with the difficulty of the disciplines (29.1%).

However, despite considering that the absence of the STS interactions in education is the cause of the disinterest of the students, it is significant that there are many teachers (89.2%) who ignore these aspects upon analyzing materials used routinely in physics and chemistry classes. Thus, concerning the analysis of the introduction of the concept of energy in a secondary education textbook in which the relative aspects of STS aren't presented, the results clearly showed the slight consideration the majority of teachers gave toward such aspects, in which only 10.8% noted the absence of these aspects in the material upon analization, pointing them out as something to take into account in instruction. Therefore it's to be expected that if the majority of the teachers don't take
into account the absence of the interactive STS aspects as something necessary, then they evidently don't transmit a complete and contextualized image of science to the students. Many explain their attitude of not opening up the discipline to the daily life as the base of structural problems, the time schedule (lack of time), the extention of the official contents, etc., and carry out programs that allow the students to accede to previous scientific studies, but without developing those that promote the acquisition of useful knowledge in order to comprehend the scientific and technical environment.

In the same manner, coinciding with other studies (Hodson, 1992) while working on our investigation, creating concrete activities of the STS relationships, the lack of interest on a great part of the teachers for some of the fundamental STS aspects (some even think that they don't have to take these into account in instruction, that these aspects aren't their job to exercise in the discipline, supporting the "neutral" character of science as the deposit of an impartial knowledge that ignores the serious historical conflicts) was evident (Table II). Although a large number (55.8%) of the 120 teachers consulted in this case proposed activities of interaction between science and technology, in general they were simple technical applications of science, confirming the idea that they are less conflictive, constitute the most "neutral" aspects and are less "removed" from the scientific content. The multiple activities established contained all the STS relationships, together with other types of activities. The examples described refer to the implications of science in the environment, in society or in technology, but in no case the opposite, that is, there weren't any activities about the implications of technological development, society or environment in scientific progress, for example.

The results are consistent with our hypothesis, which is easily explained if we consider the teacher training, where the STS aspects aren't taken into account and, therefore,
there are few reasons to hope that the teachers will have visions of science and STS relationships different from the students (Fleming, 1988).

**The STS interactions in physics and chemistry classes. A proposal for setting up a new model for the teaching/learning of the sciences**

After establishing the problem, a proposal developed that, in the context of a new model for teaching/learning, could contribute to improve the interest and attitude of the students towards the sciences and their study, contributing to show a vision of science which is more contextualized and more in accord with the current philosophical and historical positions of science.

With a minimally detailed treatment of STS interactions in teaching, we think that it is possible to improve the attitude of the students' towards physics and chemistry, increasing their interest to the study of science in general, and improving their learning, providing a more complete and appropriate image of science and how scientists work.

The proposal is basically founded on the establishment of a new model of teaching/learning which carries out the experience of dealing with the STS relationships. In this way, the work can bring together many projects which set up learning with a constructivist orientation, such as the treatment of problematic situations of interest unifying the habitual separation between activities of the introduction of concepts, the solution of problems and practical work, responding to the characteristics of a directed investigation, (Gil et al, 1991) in which the students' learning is organized as a constructuion of knowledge following their own conceptions and involving them in an investigative activity directed by the teacher.
The parallel established between the learning of science and investigation allows integration of new didactic advances and among those directing the attention towards other aspects inseparably related to the work of scientists as they are the frame in which the said scientific knowledge is developed. This teaching method also emphasizes the relationship between scientists and the outer environment, that is the influence of society in scientific and technological progress, the problems that their development generates or resolves, the necessity or convenience of development in a determined direction, the influence of scientific knowledge in society, in the exchange of ideas, in other words, the complex STS interactions which mark scientific development.

The inclusion of these aspects in the teaching of the sciences will encourage:

a) demonstrating a more socially contextualized image of scientific knowledge.

b) making a careful study of the problematics associated in their construction, which will aid in better understanding the role of science and technology, and the scientist.

c) engaging the students in the solution of serious problems which mortgage the future of humanity: the destruction of the natural environment, polarization of rich and poor populations, diseases, nuclear arms, etc.

d) succeeding in transforming the teaching of sciences into a fundamental element of our culture, in order to train critical and responsible citizens (Gagliardi and Giordan, 1986; Hlebowist and Hudson, 1991), not only for their professional efficiency, but also so that they can actively participate in social matters, contributing in this way to give meaning to studies made and favoring interest and positive attitudes.

This proposes the concept of the curriculum such as programs of activities through which the students can construct and acquire knowledge, at the same time they familiarize themselves with the basic characteristics of scientific work and they acquire...
a critical interest for science and its repercussions. In such programs the introduction of the STS activities is consistent with the established model, pervading all aspects of learning (Vilches, 1993), from the solution of problems, practical work or the introduction of concepts to their own process of evaluation. That is, not renouncing the construction of coherent bodies of knowledge, nor presenting the construction of the same as something removed from the STS interactions.

This doesn't imply increasing the curriculum, it doesn't mean adding something new to the scientific studies with the object of forming scientists or future citizens of society, but rather it deals with trying to provide a more contextualized idea of science pervading the development of didactic units with activities that take into account the cited aspects, converging with the idea that the main objective of teaching science should extend itself beyond the scientific contents, recognizing the role of science and technology as a method of solving problems of humanity with the benefits and inconveniences that their development raises.

Developing as the objective the integrated comprehension of the scientific knowledge, the social themes that surround the technological development and potentially increasing abilities in order to make decisions in a technological society (Fleming, 1989), will remove that ambivalent feeling generated between scientific and technological development and its social role that opposes a primarily optimistic vision based on the idea of technology as an instrument of prosperity with a rejection of the products the technological era and its consequences.

**Instruments developed**
In order to move ahead with the project, first we prepared materials for the introduction of STS interactive activities in the classes of physics and chemistry, which were used with 240 students of 15-17 years of age in the secondary levels by different teachers and in different centers during the 1990-1991 and 1991-1991 courses, using the same methodology.

The project dealt with carefully planned and studied programs in which the activities of the STS relationships were presented in each of the aspects of learning, aiming for an internal consistency in the development of the topic, integrated in such a way trying to give meaning to the work of the students, contemplating the entirety of the complex interactions, without forgetting the more conflictive aspects. Students are involved in different activities from technical applications and the influence of the technological development in the scientific advancement, to the mutual implications of science and technology in society, in the environment, at present and throughout history, from the different social, economic, cultural, philosophic, etc, points of view, to evaluate activities and make decisions about different aspects such as economic and social transformations, large scale military projects, different effects of development, environmental impact, contribution of science and technology to the solution of problems, etc.

Considered as useful tools in learning, the STS activities were always implemented when possible. The abstract and decontextualized activities of solving problems or the introduction of concepts for others put the student in contact with the world around him/her, with current problems and their possible solutions, establishing at the same time activities outside the learning center, discussion of scientific news, visits to the rooms of professionals or experts in dealing with questions. Some of the STS activities established a mode of introduction like the previous discussion of the interest of problems posed, favoring in this way a more positive attitude toward the work being
done; other activities used upon finishing the topics, of a globalizing form, included various aspects to the mode of summary and of reviewing the work dealt with as a possible evaluation of the learning process.

By making a detailed examination of the STS interactions in the science classes, the students were able to develop a more complete and contextualized image of physics and chemistry, as well as an increase of interest towards their study. A selection of items that reflected the ideas of the students was used which referred to the STS relationships as well as the students interest towards the study of science that was already used in the first part of the work (Solbes and Vilches, 1992) in order to make the ideas of the students clear as to their image of science and scientists in the situation that they are given in routine teaching that doesn't take into account the STS relationships as they are established in this article.

**Results**

At the end of the courses, the ideas of the STS aspects, implied in the first questionnaire, which dealt with bringing to light the image of science and scientists, were passed onto the students.

Differences exist in some items: between the groups of our students (Experimental Group 2) and those of the other teachers (Experimental Group 1) that followed the same methodology and materials, but in all cases, significant differences were observed in respect to the students that didn't take a course involving the STS interactions (Control Group).

The results showed globally that significant differences between the educational levels analyzed were not observed. The results (Table III) confirmed that the students developed an improved image (more real and contextualized) of physics/chemistry.
Dealing with the STS interactions in the classes established science as something live, more complete and integrated in their environment, in the continuing evolution that helps in solving problems that ought to help resolve those that development generates, allowing the students to better understand their role and that, at the same time, as was observed in the debates and responses, contributes to generate a "critically" positive attitude towards physics/chemistry and their study.

The students that didn't take a course in which the STS activities were established throughout the topics, not only weren't capable of making a critical evaluation in 44.8% of the cases, but also when they were asked to critically analyze the role played by physics/chemistry in the lives of men and women, weighing the advantages and inconveniences, which for the majority of the students were much more serious (destruction of the planet! end of humanity! pollution, nuclear bombs) and irreversible than the advantages, confused in the majority of cases science with the most negative consequences of social and political development like the arms race of the destruction of the natural environment. However, we think that the discussion of the social role of science, the myth of the neutrality of the scientist or the conditioning of scientific progress clearly contribute to the returning the potency and vitality to the teaching of the sciences.

It was observed in Table IV that we showed only the results related to the fact that the students who took a STS course showed an improved attitude towards physics/chemistry and their learning, and a greater interest for their study when they included interactive STS activities.

When asked which factors would contribute to increase their interest in the study of physics/chemistry (item 2), the highest percentage in the experimental groups (79.6%)
as well as in the control groups (76.%), corresponded to aspects related to the methodology used by the teaching staff and also in a high percentage in the case of the experimental groups (44.6%) to include aspects related to the STS interactions. It's interesting to note that only a percentage of 10.4 of the experimental groups and 9.0 of the control groups pointed out the difficulty of the subject as a factor that could contribute to the disinterest or the negative attitude towards physics/chemistry, citing however in high percentages (80.2 control group and 88.3 experimental group) aspects related to the teacher's method as factors directly related to their negative attitude or disinterest.

When asked more concretely which topics could be dealt with in a physics or chemistry course that would make it interesting for them (item 3), both groups of students pointed out a significant percentage of aspects related to the STS interactions, (greater logically in the case of the experimental groups that had been in contact with the STS interactions throughout the course), current topics, environmental relationships, relevant to their daily lives, applications of the subject, influences in technological development, relationships between science and the natural environment, and science/technology and society.

**Conclusion and perspectives**

The results of the investigation make clear that it is possible to transform the physics and science material with the inclusion of the STS activities along with the development of each topic, in such a way that the students can build scientific knowledge, integrating essential aspects that affect the scientific activity and contribute to deepening their knowledge.
On the other hand, it can be observed that: a) the students that had taken a course which dealt with the STS activities in the didactic model have a more contextualized, more real image of science, showing significant differences in all cases regarding the student that has taken a course without taking into account these aspects; b) it is possible to improve the attitude of the students and to increase their interest in the study of physics and chemistry dealing with the aspects pointed out by the students.

But the most global solution will be that it confronts taking into account the problem of the attitude towards science penetrating all aspects of learning, from the forms in the introduction of the concepts or the orientation of practical work to the contents or the atmosphere of the classroom. It will be necessary to establish concrete proposals from the different aspects of the teaching, tending to generate positive attitudes towards science and the learning of it, maximizing if we take into account as the didactic investigation has made clear, that a positive attitude towards science in the students develops an improved comprehension and achieves the best results overall in the learning of the subject. (Yager and McCormack, 1989).

Considering that the treatment of the STS interactions contribute to improve the image of science, to increase the interest of the students in the subject and study of physics and chemistry not only by its motivating character, but also overall because it helps to show a more contextualized image of these disciplines, the inclusion of the study of said aspects in the teaching will be important not only for the forming of future citizens of a society that is penetrated more and more by science and technology, so that in the future they can adopt an attitude that is responsible and founded in facing scientific and technological development, leaving behind visions of "pure" science, without relating it to the outer environment and with the problematic that its development generates.
Also one consequence of the investigation could be the design of STS subjects for the students that do not choose science options in the line of demonstrating science as one of the fundamental elements of the culture of our time, contributing to the development of one of the most fruitful fields of didactic investigation of the sciences in recent years and that permits a better understanding of the situation of change that teaching and the sciences are experiencing in the philosophic and historic fields.

References


<table>
<thead>
<tr>
<th>TABLE I</th>
<th>STUDENTS' INTEREST IN PHYSICS AND/OR CHEMISTRY</th>
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</thead>
<tbody>
<tr>
<td>Students who choose physics and/or chemistry because:</td>
<td>Percentage (N=212)</td>
</tr>
<tr>
<td>It is necessary for their professional study</td>
<td>44.9</td>
</tr>
<tr>
<td>It seems like an interesting subject</td>
<td>25.2</td>
</tr>
<tr>
<td>Something less bad: they don't like or are less interested in the other options</td>
<td>19.5</td>
</tr>
<tr>
<td>There wasn't any other option, thus they chose this one</td>
<td>10.3</td>
</tr>
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<table>
<thead>
<tr>
<th>TABLE II</th>
<th>PROPOSAL OF ACTIVITIES BY THE TEACHERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers, in preparing materials, proposed STS activities of:</td>
<td>Percentage (N=120)</td>
</tr>
<tr>
<td>Science/Technology relationship</td>
<td>55.8</td>
</tr>
<tr>
<td>Science/Society relationship</td>
<td>10.8</td>
</tr>
<tr>
<td>Science/Environment relationship</td>
<td>8.3</td>
</tr>
<tr>
<td>Science/History relationship</td>
<td>0.8</td>
</tr>
<tr>
<td>Activities outside the learning institution</td>
<td>4.2</td>
</tr>
<tr>
<td>NON-STS activities</td>
<td>7.5</td>
</tr>
<tr>
<td>Multiple activities</td>
<td>13.3</td>
</tr>
</tbody>
</table>
### TABLE III

**STUDENTS' VIEW OF PHYSICS/CHEMISTRY AND THE STS RELATIONSHIPS**

<table>
<thead>
<tr>
<th>Percentage of students that indicated:</th>
<th>Control N=212</th>
<th>Exp. 1 N=91</th>
<th>Exp. 2 N=149</th>
</tr>
</thead>
<tbody>
<tr>
<td>A critically positive image of physics/chemistry</td>
<td>33.5</td>
<td>68.8</td>
<td>68.8</td>
</tr>
<tr>
<td>An uncommonplace view of scientists</td>
<td>5.7</td>
<td>33.0</td>
<td>55.0</td>
</tr>
<tr>
<td>Five or more technical applications of physics/chemistry</td>
<td>13.2</td>
<td>51.6</td>
<td>75.2</td>
</tr>
<tr>
<td>Three or more influences of physics/chemistry in society</td>
<td>8.0</td>
<td>31.9</td>
<td>59.7</td>
</tr>
<tr>
<td>Three or more influences of society in physics/chemistry</td>
<td>4.2</td>
<td>15.4</td>
<td>33.6</td>
</tr>
<tr>
<td>Three or more influences of physics/chemistry in the environment</td>
<td>8.0</td>
<td>20.9</td>
<td>46.3</td>
</tr>
<tr>
<td>They were capable of making a critical evaluation</td>
<td>55.2</td>
<td>83.5</td>
<td>96.0</td>
</tr>
</tbody>
</table>

### TABLE IV

**STUDENTS' INTEREST IN PHYSICS/CHEMISTRY AND THE STS RELATIONSHIPS**

<table>
<thead>
<tr>
<th>Percentage of students who:</th>
<th>Control N=212</th>
<th>Exper. N=240</th>
</tr>
</thead>
<tbody>
<tr>
<td>positively valued the teaching of physics/chemistry</td>
<td>26.4</td>
<td>54.2</td>
</tr>
<tr>
<td>indicated the STS interactions as a factor that could increases their interest for physics/chemistry</td>
<td>15.1</td>
<td>44.6</td>
</tr>
<tr>
<td>cited aspects of the STS interactions as interesting during the course</td>
<td>37.4</td>
<td>65.8</td>
</tr>
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THE STS INTERACTIONS AND THE TEACHING OF PHYSICS AND CHEMISTRY

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ABSTRACT
The absence of STS interactions in the usual teaching of science in Spain is analysed in this work. It goes on the proposal of introduction of STS interactions in Physics and Chemistry classes in conjunction with the teaching/learning model of science as investigation.
ABSTRACT
The absence of STS interactions and its consequences in the usual teaching of science in Spain is analysed in the first part of this work. (It goes on the proposal of introduction of STS interactions in Physics and Chemistry classes in conjunction with the teaching/learning model of science as investigation). When such interactions are not introduced, a view (of the science) remote from everyday reality and the ignorance of the relationships between science and technology is shown by the students. This leads them to a lack of interest in the study of Physics and Chemistry. Not only the absence of STS interactions in the textbooks contributes to an out of context view of the science but also, the fact that just a few teachers attach some importance to the teaching of all these aspects.
In the second part of the article, the results obtained were taken from an experience carried out with students of the three last courses in the secondary levels (16-18 years). By using STS interactions activities in Physics and Chemistry classes significant improvements have been achieved. The students get to have a comprehensive knowledge and a more accurate view of these sciences and, moreover, they are able to understand they way scientists work. All this will help the students to improve their interest and attitude to the study of physics and chemistry. The results of this research highlight the possibility of bringing about changes in the materials used in physics and chemistry, with the introduction of STS interactions, so that the students may build scientific knowledge. Likewise, they will elaborate essential aspects which will affect the scientific activity and contribute to the depth and consolidation of their own knowledge.