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DO HIGH-SCHOOL STUDENTS' PERCEPTIONS OF SCIENCE CHANGE WHEN ADDRESSED DIRECTLY BY RESEARCHERS?

Laurence Simonneaux

Virginie Albe

Christine Ducamp

Jean Simonneaux

ABSTRACT. The Universitй des Lycйens (University of High-School Students) was set up in France in order to make scientific knowledge more relevant to students and to combat a growing lack of interest in science among students. The scheme involves a series of lectures to students by scientists, each followed by a debate. The organisers hope that putting students in direct contact with researchers will motivate them and enable them to envisage the nature of science and careers in science in a different way. Each of the three lectures covered by this study focused on a socio-scientific issue. In spite of the socio-cultural differences observed, the students have a positive opinion of science, scientists and careers in science. But, in the meanwhile, they believe that scientific research may have negative effects. The lectures had little effect, either on their prior conceptions of science and scientists, nor on their acquisition of knowledge.

KEYWORDS. Nature of Science, Socio-Scientific Issues, Careers in Science.

FRAMEWORK AND PROBLEM

The Universitй des Lycйens (University of High-School Students) was set up in France by the Mission d'Animation des Agrobiosciences or MAA in order to make scientific knowledge more relevant to students and to combat a growing lack of interest in science among students. The scheme involves a series of lectures to students by scientists, each followed by a debate. The organisers hope that putting students in direct contact with researchers will motivate them and enable them to envisage the nature of science and careers in science in a different way.

For each session, the main speaker is a researcher. The researcher covers a scientific field based on his own individual experience but also on the collective experience in his field (i.e. evolution, challenges, constraints, motivation, issues under debate, among others).

The lecture is completed by another speaker from another field or professional sector, who reacts to the researcher's speech.

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Each lecture is delivered to between 200 and 400 students. Each of the three lectures covered by this study focused on a socio-scientific issue. They were entitled "Plants: miniature chemical factories", "What will tomorrow's climate be?" and "Can economics help Africa?". We analysed the effect of the first lecture on 136 students, that of the second on 177 students and that of the third on 287 students. All the students came from one of three main categories, general, technical or professional courses. There was a further difference concerning students in the general category, who came from either economics or science streams.

Conferences

The conference: "Plants: miniature chemical factories"

The lecturer had to deal with the following themes: Plant cells are capable of synthesizing tens of thousands of molecules including the most complex ones. How does this occur? What types of substances are produced in this way? The lecturer also had to cover the various ways plant cells are used by industry and their incredible potential which still has to be exploited, in particular for research in the fight against cancer.

Some comments by the authors on this lecture

The lecturer, after having developed the theme described above, illustrated it by means of two applications which are exemplary of plant biotechnology, which is the lecturer's field of research: the production of golden rice enriched with vitamin A, and the production of gastric lipase to combat the symptoms of cystic fibrosis.

The development of plant biotechnology led to debates as to the their repercussions. These are controversial issues. We shall describe their definition below. In our opinion, the teaching of plant biotechnology involves a new challenge as it requires training informed people who are capable of taking well-founded decisions in spite of the uncertainty and of participating in social debates on the development in question. As indicated by Legardez, teachers, when confronted with socially controversial scientific issues, sometimes try to 'cool them down'. We wonder whether this was not the case here. A controversial or 'hot' body of knowledge such as the production of genetically modified plants was dealt with here in a diplomatic or 'cooled down' way during the lecture. The lecturer moreover refused to answer questions on GMOs.

The scientific content of the lecture was very challenging.

The conference: "What will tomorrow's climate be?"

The lecturer had to deal with the following themes: Which climatic changes may occur between 50 and 100 years from now? Is the planet actually heating up? Once again, this led to a debate on scientific knowledge. What is the status of our current knowledge on this issue, the tendencies and different scenarios, the consequences on the level of the oceans, snow fields in mountains, agriculture, water reserves? What should be done to fight this trend and at what cost?

Some of the authors' comments on this lecture

The lecturer gave a fairly 'didactic' lecture on weather forecasting and its limits on climatology, on how the greenhouse effect functions and why it is necessary and on the causes of global warming while only considering the extent of global warming and not whether it was a reality. It should be said that there is a debate today concerning the 'hockey stickcurve', which is a symbol of planetary warming and which was published in Nature in 1998. Among the means being considered to fight the consequences of global warming on agriculture, the speaker described the development of transgenic plants capable of resisting drought.

The conference: "Can economics help Africa?"

The lecturer had to deal with the following themes: Economic science is not only useful to developed countries, but can also help poor countries to develop and lay the basis for peace on condition that it be adapted to the reality of those countries, since not all economic recipes are suitable for all countries. How much does it cost to develop the economies of poor countries and how can economics help prevent civil wars in Black Africa?

Some of the authors' comments on this lecture

This lecture stood out due to the 'friendly' personality of the speaker. He dealt with the use of mathematics in economics but also the importance of field surveys.

Socio-scientific issues

One of the goals of science education is to help students develop their understanding of how society and science are mutually dependent. This is the educational school of thought known as 'Science-Technology-Society' (STS) and it includes the study of controversial scientific issues. These issues lead to debates on the production of reference knowledge; they are omnipresent in the social and media environment.

In science education the notion of 'socio-scientific issues' has been introduced as a way of describing social dilemmas impinging on scientific fields (Gayford, 2002; Kolstoe, 2001; Sadler et al., 2004; Zeidler et al. 2002, Yang, 2005, Patronis et al., 1999…). These are issues on which people have different opinions and which have implications in one or more of the following fields: biology, sociology, ethics, politics, economics and/or the environment. Socio-scientific issues are controversial since they are intrinsically unpredictable.

The educational challenge is to enable students to develop informed opinions on these issues, to be capable of making choices with respect to preventive measures and to intelligent use of new techniques and especially to be able to debate such issues. This means, among other requirements, that students have to understand the scientific content involved, including the epistemology and that they must be able to identify controversial topics and analyse their social implications (in economic, political and ethical terms, etc.). A person whose is 'literate' in science should be able to understand and participate in debates on 'socio-scientific" issues. In order to solve most problems arising in modern society, scientific solutions alone are not enough, in other words, they must also take into account the social implications of decisions relating to scientific investigation (Sadler et al., 2004 a & b ; Zeidler et al. 2002).

Given the increasing importance of many socio-scientific issues (biotechnology, environmental problems, etc.) in modern society, each student is already having to or will have to make decisions on such issues and schools should thus help them prepare to be informed citizens.

As named by Edgar Morin (1998), the issue raised is 'an historical and henceforth crucial problem of cognitive democracy'. Socio-biological issues, in Edgar Morin's terms, are 'polydisciplinary', multidimensional, transnational and in a context of increasing globalisation, planetary in nature. We believe that this didactic approach fits Edgar Morin's analysis well in that it is education based on 'the necessity of reinforcing critical thinking by linking knowledge to doubt, by integrating particular knowledge in a global context and using it in real life, by developing individuals' ability to deal with fundamental problems with which they are confronted in their own historical epoch'.

Conceptions of science, science education and the scientific professions

We based our investigative method on various research projects carried out at an international level on students' attitudes to science. This research highlighted the influence of various factors such as gender, school curricula, culture, etc. This issue was discussed in an excellent literary review published in September 2003 by Osborne et al.

A set of behavioural characteristics leading to a generally positive attitude to science was classified as follows:

- the manifestation of favourable attitudes towards science and scientists;
- the acceptance of scientific inquiry as a way of thought;
- the adoption of 'scientific attitudes';
- the enjoyment of science learning experiences;
- the development of interests in science and science-related activities; and
- the development of an interest in pursuing a career in science or science related work. Klopfer (1971)

Several studies (Breakwell & Beardsell, 1992 ; Brown, 1976 ; Crawley & Black, 1992 ; Gardner, 1975 ; Haladyna, Olsen & Shaughnessy, 1982 ; Keys, 1987 ; Koballa, 1995 ; Oliver & Simpson, 1988 ; Ormerod & Duckworth, 1975 ; Piburn, 1993 ; Talton & Simpson, 1985, 1986, 1987 ; Woolnough, 1994) have incorporated a range of components in their measures of attitudes to science including:

- the perception of the science teachers;
- anxiety toward science;
- the value of science;
- motivation towards science;
- enjoyment of science;
- attitudes of peers and friends towards science;
- the nature of the classroom environment;
- achievement in science; and
- fear of failure on course.

It should be noted that students may express their interest in science while not doing so when in the company of other students who do not share this interest. Adolescents are strongly influenced by group norms. Thus, Head (1985) considers that adolescence is a moratorium period during which the development of the personality is suspended and thus affected more by normative peer group expectations. For instance, it seems to be 'normal' for boys to study science and not for girls. Conforming is thus a way of establishing gender identity.

A distinction should be made between students' attitudes towards science and towards the learning of science. For instance, Whitfield (1980) and Ormerod (1971) asked students to classify their interest in different school disciplines. We followed their example by adding a question on the fear of failure in the various disciplines.

Recent research was undertaken on the relationship between attitude towards scientific disciplines and students' achievements in 3 countries (Australia, Cyprus, USA) (Papanastasiou & Zembylas, 2004). A computer model was built to analyse this correlation. The variables taken into account are the individuals' perception of competence and individuals' inclination to study biology, Earth sciences, physics and chemistry and the significance attached by fathers, mothers, friends and the individuals themselves to their achievements in scientific disciplines.

The research mentioned above demonstrates that environmental factors do influence students' attitudes to science, particularly their socio-economic background, enjoyment of science learning, fear of failure, extra-curricular activities (especially those carried out with the student's father), childhood experiences (e.g.: use of introductory science kits and games) and the attitudes of peers and friends. Is this also true for our sample group of students?

In society, science education specialists are increasingly studying the nature of science and the interdependence of society and science (Sadler et al, 2004). The consensus on the nature of science is as follows: some scientific knowledge is relatively stable while other knowledge is more provisional and likely to change according to new results or because previous results have been reinterpreted (Harding & Hare, 2000). Science is based on empirical proof and scientists use their creativity to obtain and interpret this proof. Scientific research and cultural norms mutually influence each other (Sadler et al., 2004). Knowledge of the nature of science affects the analysis of socio-scientific issues. In order to be able to deal with this type of issue, students have to know how to recognize and interpret data, to understand how different social factors can have different effects and to understand that stakeholders often have diverging opinions (Sadler et al., 2004). How do our sample students perceive the nature of science? What are the students' views on the interactions between science and society? Which factors affect scientific research? Does scientific research have an impact on society? If so, what kind of impact?

It should not be forgotten that attitude is a lasting quality whereas knowledge is ephemeral (Osborne, Simon & Collins, 2003, Simonneaux, 1995).

One criticism which could be made is that the methods used for measuring opinion only see the tip of the iceberg. These methods were therefore supplemented by a series of semi-directive interviews, in order to identify and better understand the students' opinions and their origins.

METHODS

We evaluated the amount of scientific knowledge acquired by students concerning subjects discussed in lectures and the subsequent effect on their perceptions of science, science education and the scientific and technological professions. This process entailed several phases:

- Interviews with the lecturers for the purpose of drawing up a thematic questionnaire,

- Prior to the lecture, completion of a questionnaire on what science, science education and the scientific and technological professions meant to the students. This questionnaire was supplemented by thematic questions aimed at establishing how much the students already knew about the subject of the lecture.

- After the lecture, completion of a second questionnaire designed to measure changes in viewpoints and knowledge acquired on the subject.

- In-depth interviews with a sample group of students.

In this paper, we mainly describe the results of the lectures on students' perceptions of science, scientific teaching and scientific professions.

FINDINGS

What do high-school students think of scientific studies and school disciplines?

The pre and post test questionnaires described in this section included in all 27 questions, 18 of which referred mostly to the socio-cultural characteristics of high-school students, to the projects with respect to training and profession, to their inclinations and fear of failure with respect to courses in different disciplines and to their informal, extracurricular scientific activities. The answers to these questions should not vary significantly after the lecture and should enable us to check the reliability of the questionnaire.

The 9 other questions concerned their opinion of scientists, the usefulness of scientific research for society, their feelings about the development of research, the goals and possible risks involved in scientific research, the products of scientific disciplines and factors which influence research and researchers.

Students' socio-cultural characteristics

The extent to which the study course taken depended on the father's profession is very significant. High school students in courses which are supposed to lead to science studies tend to come from well-off families. This leads to the disquieting question: Can school act as a social elevator or does it simply reinforce social reproduction?

Students on science courses tend to also have friends who are considering careers in science[1] (VS). This is consistent with other results demonstrating the influence of peers' and friends' opinions of science. They also receive more encouragement from their parents to undertake scientific studies (S).

Thirty-four point three percent of students consider taking scientific studies and 44.6% do not intend doing so.

The dependency between classes and training projects was found to be very significant: for the S-stream (science) students alone, more than 70% are considering scientific studies for their future, whereas 70 to 100% of students in economics, technological and professional streams, are not.

Enjoyment and fear of failure with regard to different subjects

Most of the students in the sample population liked the various subjects. Enjoyment can come from various sources: pleasure in studying the subject, the quality of the teaching, the marks obtained, etc.

More than 27% of the students said they enjoyed their biology courses 'a lot' and '57%' liked them 'quite a lot'. The dependency between classes and inclination was very significant:

[1]NS = non significant dependence; S = significant dependence; VS = very significant dependence.

economics-stream students were the least enthusiastic, with more than 21% claiming that they do not like biology 'at all' (as against 4% for the overall sample population). More than 50% of S-stream students liked biology 'a lot'.

Let us now consider the answers for which the percentages are the highest:

- fifty-five percent of the students liked the geography course 'quite a lot' (25% of S-stream 'did not like it' as opposed to 12% for the overall sample population (VS)).
- fifty percent liked their history class 'quite a lot'.
- forty-eight percent liked their mathematics class 'quite a lot' (VS).
- forty-five percent liked their physics class 'quite a lot' (VS).
- it is logical that 70% of the economics-stream students like economics 'quite a lot'.
- forty-six point six percent of the students liked chemistry classes 'quite a lot' (VS). More than 30% of students in a professional stream 'did not like' chemistry (as opposed to 13% for the overall sample population) and 31% of economics-stream students 'did not like' chemistry at all' (as opposed to 7% for the overall sample population).

And 85% of students liked doing practical work.

Concerning the fear of failure:

- 45.8% were not afraid of failure in biology (S),
- 55% were not afraid of failure in geography,
- 48.3% were not afraid of failure in history (VS),
- 49.5% were afraid of failure in mathematics (VS),
- 50.9% were afraid of failure in physics (VS),
- 42.4% were afraid of failure in chemistry (VS).

Obviously, the more individuals are faced directly with tests in the various subjects, the more afraid they are of failure. No change in opinion was noted between pre- and post-testing, which confirms the internal validity of the study.

Does the study of science make students intelligent? Is it easy to study science? Does the study of science help find a job?

Sixty-seven point seven percent of the individuals believed that studying science in high school does not make them more intelligent than when they study other disciplines (VS). 43.8% believed that studying science is neither easy nor difficult; 2.4% believed that it is very easy, 10% that it is easy, 35.3% that it is difficult and 8.9% that it is very difficult (there was a very significant dependency between classes, in particular 27,3% of students in the professional stream believed that it is very difficult).

Forty-one point three percent believed that scientific training would help them to find work; 32% did not know. The dependency was very significant between classes: about 60% of students in the S-stream and 54% in the first year of high school believed this to be true. Almost 35% believed that studying science at high school would help them solve problems of daily life and more than 27% believed that it would not help them more than the study of other disciplines (VS).

What do they think of scientists and scientific research?

Overall, the students' opinions of the scientists and of the value of scientific research were found to be positive. 55.3 % had a favourable opinion of the scientists; 61.7 % considered that scientific research is beneficial to society; 32.2 % were enthusiastic about progress in scientific research; 41.8 % were neither concerned nor enthusiastic and 18.7 % were concerned. Students in science courses were the most positive (VS), except for those who were considering careers in the environmental sciences, who were the most anxious with regard to progress in scientific research.

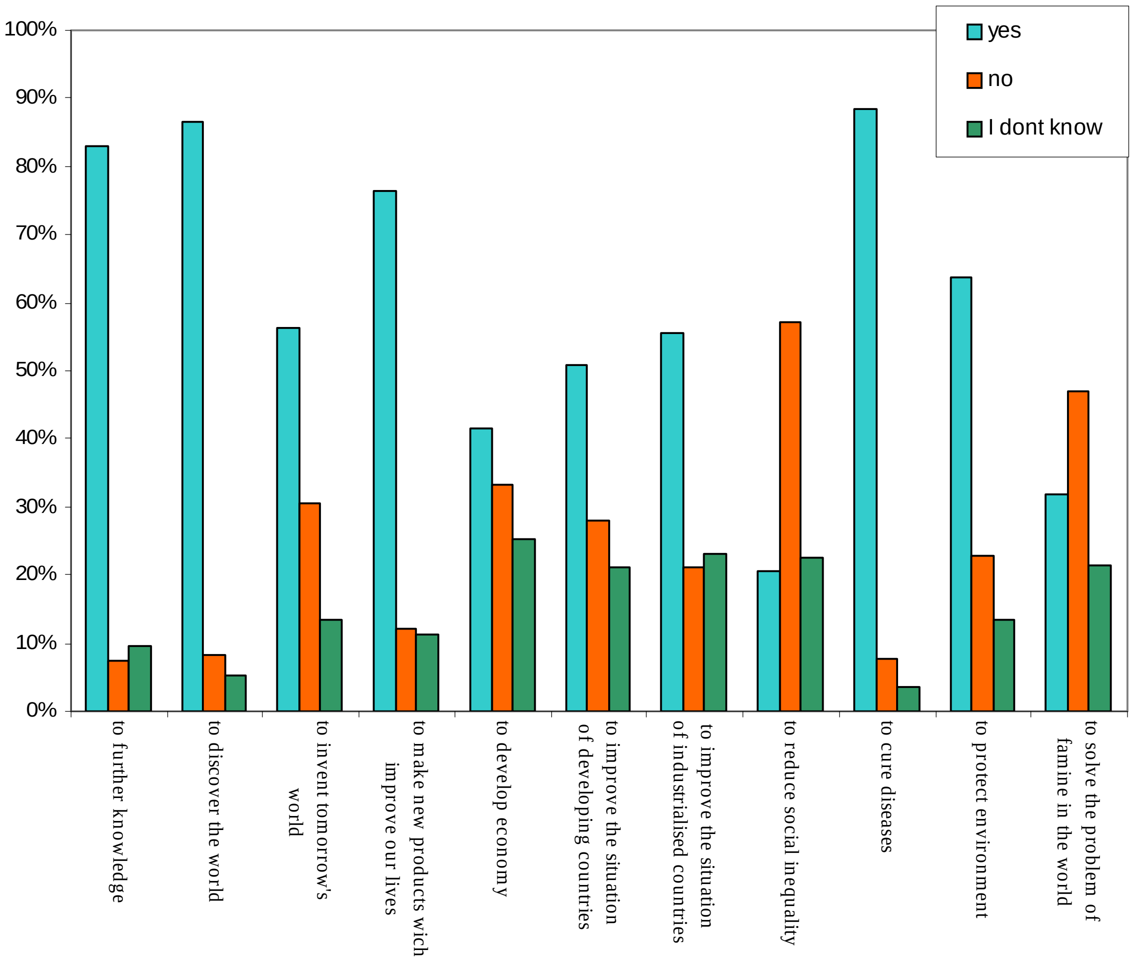


Table 1: Scientific research helps to

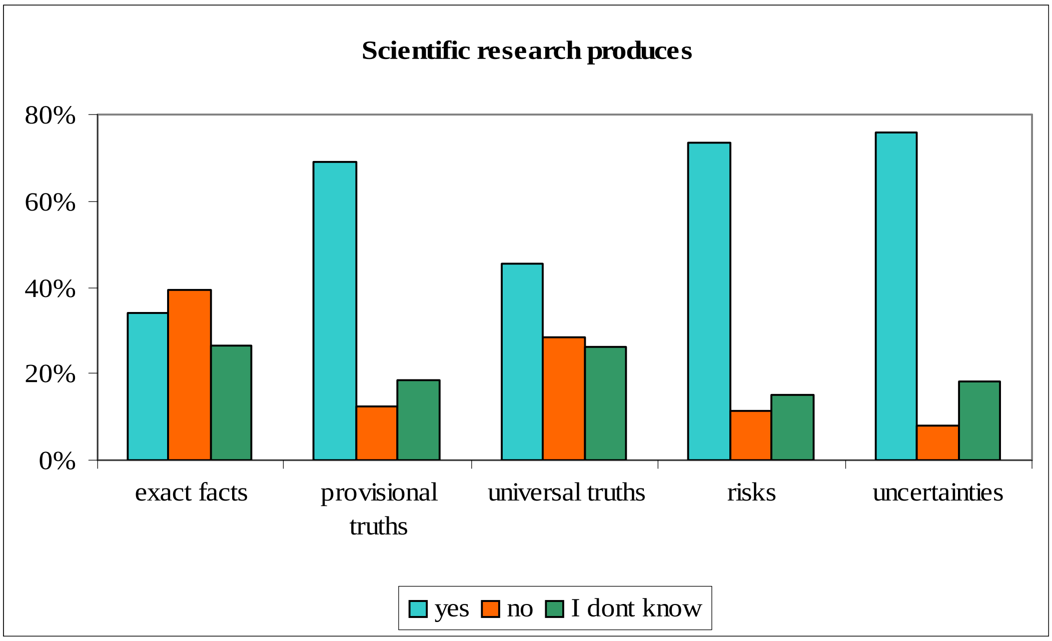
Most of the students affirmed (the ranking is in a decreasing order) that scientific research helps:

- to cure diseases (88.4%) (TS),
- to discover the world (86.5%),
- to further knowledge (83%), to make new products which improve our lives (76.5%) (TS),
- to protect the environment (63.7%) (S),
- to invent tomorrow's world (56.2%) (S) (more than 76% of S students believed this to be true and more than 63% of students in professional streams did not),
- to improve the situation of industrialised countries (55.6%),
- to improve the situation of developing countries (50.7%).

On the contrary they:

- did not believe that scientific research could reduce social inequality (57.1%)
- nor that it could solve the problem of famine in the world (46.9%).

Table 2 : Scientific research produces



Most of the students rightly considered that scientific research produces provisional truth. They were less sure of themselves concerning the production of exact facts (26.5% said they didn't know) and universal truths (26.3% said they didn't know), perhaps because they had not clearly defined for themselves what universal truths are? Seventy three point six percent believed that scientific research produces risks and 75.7% that it produces uncertainties.

This raises the question as to which uncertainties are they referring to, uncertain knowledge or uncertain applications of such knowledge?

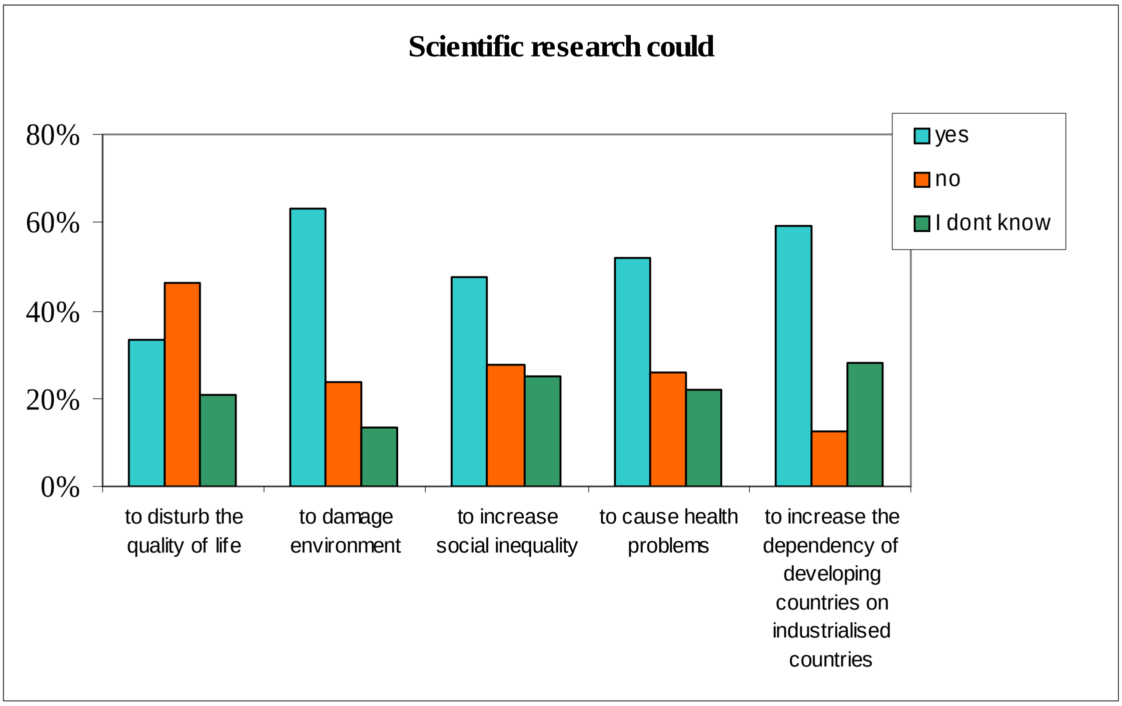


Table 3: Scientific research could

Forty six point one percent of the individuals did not think that scientific research could disturb the quality of life (though 60% of the technology students specialising in rural planning and development did think so while 20% of students in the second year of high school did not). On the contrary 63% believed that scientific research could damage the environment (but only 34% of students in the second year of high school). A majority of 59.4% of the students believed that it would increase the dependency of developing countries on industrialised countries (more than 70% of S students held that opinion). More than 52% believed that scientific research could cause health problems, 47.4% that it could increase social inequality (however 24.9% did not know what to think of that issue) and 52% of the students in the second year of high school did not believe that to be true.

What does research depend on?

In answering that question, 45.4% considered that it depends on the **moral values of the scientists** (32.3% did not know what to answer) (TS).

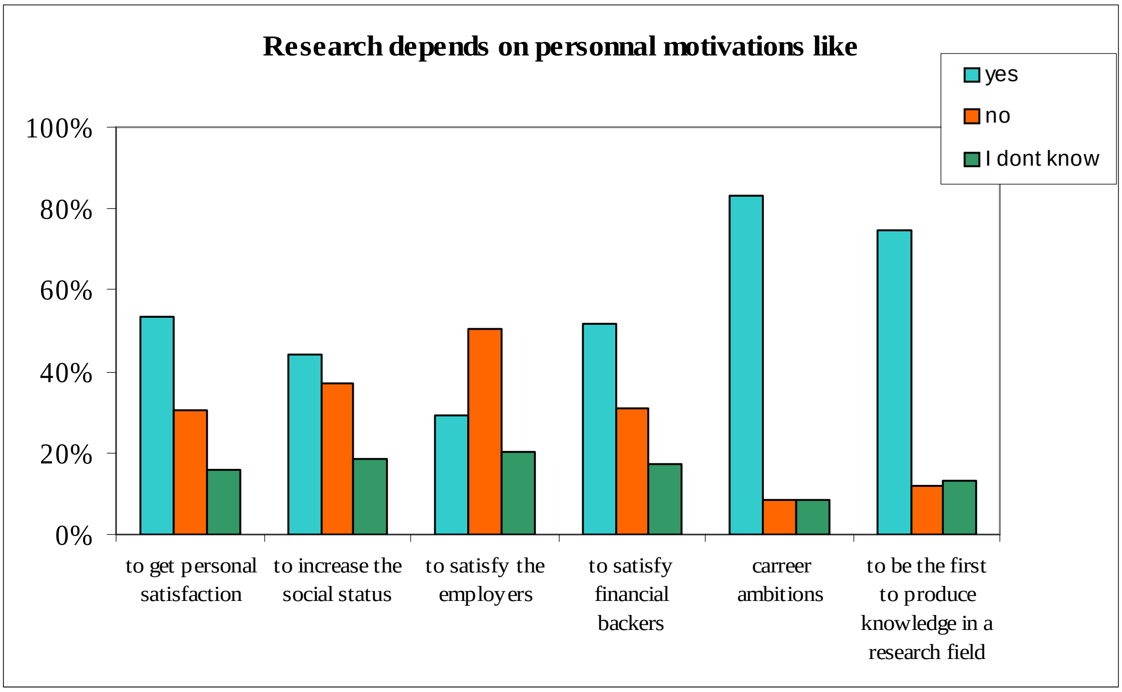


Table 4 : Research depends on personal motivations like

These students believed that researchers' career ambitions and wanting to be the first to produce knowledge in their research field were personal motivations which affected the outcome of research. Other factors, according to them, included satisfying financial backers and getting personal satisfaction out of their work. Half of the students thought that satisfying the employers was not a relevant factor. Opinions were similar irrespective of the training streams concerned.

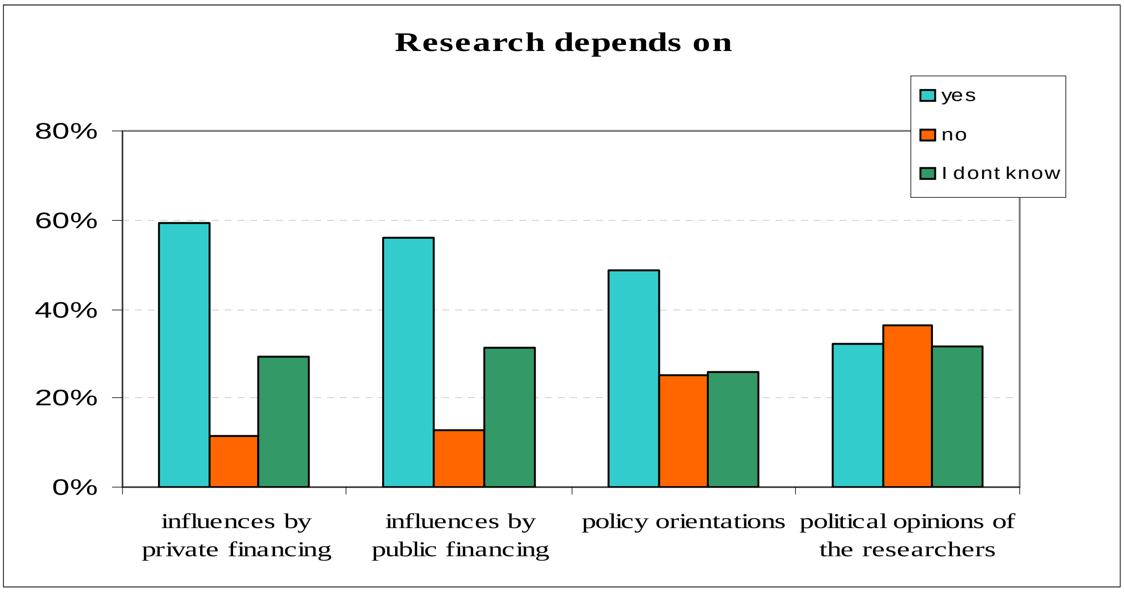


Table 5 : Research depends on

Fifty nine point two percent of the students believed that research is influenced by private financing (TS); more than 70% of S students agreed with that as opposed to 31% of students in the second year of high school; fifty-six point two percent believed that research is influenced by public financing (TS) and 31.2% admitted that they had no idea.

Forty eight point eight percent believed that research depends on policy orientations, while 25.3% did not believe this to be true and 25.9% did not know what to think (TS).

Thirty two point one percent did not think that it depends on the political opinions of the researchers, while 36.3% thought the contrary and 31.6% said that they did not know (S).

The possible impact of lecture-debates on what high school students think or know

It should be pointed out that only a few students took part in the debates (it is not easy to ask questions in an amphitheatre in front of students that you do not know), which is no indication of the relative contribution of the debates and the lectures on the students' knowledge-representation system. This system is a sum of social representations, residues from previous teaching and information conveyed by the media on the themes under discussion.

If we take an overall look at students who participated in the three lectures, we see that there was very little impact on their systems of knowledge representation, in particular on the adoption of scientific knowledge. Fewer of them believed that research helps to protect the environment (63.8% for the pre-test as opposed to 54.4% for the post-test). Does this mean that the high school students' university programme had no impact on high school students' perceptions of research? No.

We thus wanted to analyse the impact as a function of lectures which might be related to the theme, to the lecturer's delivery, but also to the fact that classes from different streams took part in them.

Fewer high school students believed that studying science in high school would help them solve problems of daily life (34.8% thought so during the pre-test, 27.4% during the post-test); it was especially those who attended the lecture on 'Plants' who changed their opinion (50% during the pre-test as against 32.7% for the post-test). And fewer of them were enthusiastic about the development of research (32.1% during the pre-test as opposed to 27.1% for the post-test), here again, it was mainly those who took part in the 'Plants' lecture who changed their mind (50.7% for the pre-test 37.2% for the post-test).

Of those high school students who attended the 'Africa' lecture, more of them thought that scientific research helped to develop economic growth (48.2% for the pre-test as against 56.5% for the post-test) and the dependency was very significant between the different lectures. There were also more of them who thought that scientific research helped to abolish social inequality (26 .6% for the pre-test as against 44.2% for the post-test); the dependency was very significant between the different lectures. Once again, more of them thought that research helped to reduce problems of famine in the world (31.9% for the pre-test as against 43.9% for the post-test), the dependency was significant between the different lectures.

Nor did the results vary for the products of scientific research (exact facts, temporary hypotheses, universal truths, risk and uncertainty) or with respect to disturbances that they might cause (deterioration of the quality of life, deterioration of the environment, increasing of social inequality, generation of human health problems, increasing dependency of developing countries on industrialised countries).

A few more of them thought that research depends on the personal motivations of researchers, such as enjoying their work (53.6% for the pre-test as against 60.6% for the post-test). Students who attended the 'Plants' lecture changed their minds more often (58.1% for the pre-test as against 72.5% for the post-test). There were also slightly more of them who believed that research depends on the personal motivations of researchers such as reinforcing their social status (44.2% for the pre-test as against 45.7% for the post-test). Once again, it was those who attended the 'Plants' lecture who changed their minds most often (41.,9% for the pre-test as against 56.5% for the post-test).

Was there a gender effect? Yes, for many variables

The dependency was very significant between gender and

- the fact of considering undertaking scientific studies: 43% of the girls as opposed to 29% of the boys.
- the idea that studying science in high school makes you more intelligent: fewer girls thought this was the case.
- inclination for geography classes: 23% of the girls did 'not like or not at all' as opposed to 10% of the boys.
- inclination for French classes: girls appreciated them much more.
- inclination for philosophy classes: 26% of the boys did 'not like them at all' as opposed to 9.4% of girls.
- inclination for physics classes: more than 24% of the girls did 'not like them' as opposed to 11.7% of the boys.
- inclination for economics classes: 23% of the girls did 'not like them' as opposed to 10% of the boys.
- inclination for language classes: 21% of the girls liked them 'a lot' as opposed to 8% of the boys.

The dependency was significant between gender and

- inclination for chemistry classes: more girls liked them than boys.

The dependency was very significant between gender and

- the fear of failure in French: the girls were less afraid.

- the fear of failure in mathematics: more than 60% of the girls were afraid as opposed to 42% of the boys.

- the fear of failure in physics: more than 63% of the girls were afraid as opposed to 42% of the boys.

The dependency was significant between gender and

- the fear of failure in languages: the girls were less afraid.

The dependency was very significant between gender and

- the fact of having friends who are considering a scientific career: girls have more friends who were considering doing so.

More girls are encouraged by their parents to do scientific studies than boys (S).

Fewer girls believed that research leads to exact facts (VS) and more girls believed that it produces temporary truths (VS).

After the lectures, more girls believed that studying science in high school would not help them more than other disciplines to solve problems in their daily lives (VS). More boys believed that research helps to improve the situation of industrialised countries (S), to reduce social inequalities (S).

Forty-five percent of the girls believed that studying science was difficult as opposed to 27% of the boys (VS).

More boys thought that research could deteriorate the quality of life (VS). The boys were also more numerous in believing that research depends on the personal motivation of scientists such as increasing their social status (S), pleasing their employers (S), pleasing the organisations that fund research (VS). Whereas more girls thought that research depends on influence due to public financing (S).

What is the social relevance of research related to?

A very significant dependency was found between the **positive** influence that high school students believe scientific research has on society and their positive opinion of scientists, the fact that research helps to improve the situation of developing countries, to invent a model for the future, to discover the world in which we live, to make new products which improve the quality of life, to improve the situation of industrialised countries, to heal serious illnesses and to protect the environment.

Conversely, those who believed that research has a **negative** effect on society believe that it can deteriorate the quality of life (VS).

The dependency was very significant between the **positive** influence that high school students believe scientific research has for society and the fact that their parents encouraged them to study science, the reading of scientifically oriented magazines and their inclination to watch a science TV programme.

The dependency was significant between the fact that high school students believe that scientific research is useful for society and the idea that it is easy to study science, if research is not influenced by public financing.

What is the decision to study science related to?

The dependency was found to be very significant between the orientation considered for scientific studies and believing that following a scientific career would help them to find work, believing that science studies are easy, encouragement from parents, the fact that friends are also considering a scientific career, that they like classes in chemistry, economics, physics, mathematics, biology, and that they believe that studying science in high school would help them to solve problems in their daily lives.

The decision to study science depends in a very significant way on the positive opinion that high school students have of scientists, of the relevance of research for society, of their feelings (enthusiasm) in relation to the development of research, to the fact that they believe that research does not depend on the political opinion of researchers, is not influenced by public financing, and to the fact that they think that research helps to protect the environment, to heal serious illnesses, to make new products which improve the quality of life.

The dependency was significant between the orientation envisaged for science studies and believing that study of science in high school makes one intelligent, believing that research helps to improve the situation of industrialised countries, to discover the world in which we live and that research does not depend on political orientations.

Which factors influence their feelings in relation to the development of research?

Students were more or less anxious or enthusiastic about the development of research according to social characteristics, such as the father's (S) or mother's (VS) profession, the encouragement of parents (VS) and according to many points of view: the opinion of scientists (VS), the usefulness of research for society (VS), the outlook for undertaking science studies (VS) or becoming a researcher (VS), the idea that undertaking a scientific career would help to find work (VS).

It also depended on their inclination for biology (VS), mathematics (S), physics (VS), chemistry (VS), practical work (S) for enthusiastic students; for history (S), philosophy (VS), economics (S), languages (VS) for anxious students. Consequently, those who liked social science were more anxious about the development of research than those who liked purely scientific disciplines and vice versa. This was not only related to students' training streams. The sample population did not include many high school students in human science streams (economics stream students). The most anxious believed that studying science is very difficult (S) and they do not read scientifically oriented magazines (VS).

This variable was also highly related, positively for enthusiastic students and negatively for anxious students, to the idea that research is useful for inventing tomorrow's world (VS), for making new products which improve the quality of life (VS), for improving the situation of developing countries (S), for improving the situation of developed countries (S), for reducing famine in the world (VS), for healing serious illnesses (VS) and for protecting the environment (S). Anxious students believed that research may deteriorate the quality of life (VS), the environment (VS), may increase social inequality (VS), may cause human health problems (VS).

Finally, this feeling of anxiety or enthusiasm was significantly dependent on the idea that research depends or not on the political opinions of researchers.

CONCLUSIONS AND IMPLICATIONS

In spite of the socio-cultural differences observed, the students have a positive opinion of science, scientists and careers in science.

The lectures had little effect, either on their prior conceptions of science and scientists, nor on their acquisition of knowledge. Thus, during the interviews, they declared that the level of the lecture was too high for them and that the lecturer talked too quickly during the 'Plants' lecture. If the experiment were to be repeated, it would perhaps be better to identify the students' system of representation and knowledge and then to define a learning base on which to build a teaching strategy, with the help of the lecturers, centred on the questions and concerns of the students and on their potential for learning and memorising. Students acquire new knowledge on socio-scientific issues via their system of representation and knowledge, i.e.: from their own social interpretation of the subject being studied. This may lead to negative or positive opinions which can stimulate or obstruct learning or their perceptions of science or scientists. Knowledge is also acquired via their previous scientific knowledge of the fields studied (information which may be incomplete, correct, or erroneous). In addition, we must not forget that the students' system of representation and knowledge is also affected by the media.

Although teachers were provided with a list of websites covering the same subjects as the lectures, the students were not assigned any preparatory work. More operational teaching aids should perhaps be created. We feel that the lectures would be of more value if they were incorporated into an overall teaching strategy, integrating both pre- and post-lecture activities, carried out in cooperation with the teaching staff. Knowledge is acquired more effectively when the method is multi episodic, i.e.: when knowledge is drawn upon at different times and in different contexts.

Finally, one last essential point needs to be made. In the lectures/debates, the students all found themselves (apart from the few who took part in the debate) in a transmission/reception scenario, corresponding to a teaching model in which they played a passive role. This observation confirms the idea that it would perhaps be better to integrate the lecture/debate into an overall teaching approach, which would enable the students to participate more actively.

The direct account of a researcher may in theory impress students. In a way, in this study we did not find that effect to be very great. But nevertheless, for socio-scientific issues, knowledge is not stable and sometimes controversial. Research itself is debated by citizens who may be researchers and who discuss its consequences. Is a researcher able to 'objectively' describe contradictory points of view? It is an illusion to believe that anyone is neutral on these issues. Furthermore, as we said above, most of the problems encountered in modern society require more than a scientific solution to solve them.

The educational challenge is to empower students so that they can contribute to the societal debates en socio-scientific issues. They must be able to identify the validity of the arguments of scientists, journalists, teachers, theirs as well as those held by other students, their value system, to understand the nature of science…

The students' line of reasoning is largely shaped by the media or their social milieu. Our intention is to get them to distance themselves from adopted arguments by encouraging them to think for themselves by analysing the information available and then to express their own thoughts on the matter. Apart from this, argumentation is an intrinsic part of learning as knowledge is gradually developed through informed debate.

The aim must be to help students to identify the criteria and information which support a point of view, , so that they can treat the issue as problematic. The most effective means of meeting this objective is discussion (in the generic sense). On condition that there are not too many participants in the debate, that each one be encouraged to participate and that the debates be based on information and content whose limits should be defined.

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Simonneaux, Laurence; Albe, Virginie; Ducamp, Christine & Simonneaux, Jean

ENFA

BP 22687

31326 Castanet-Tolosan cedex **FRANCE**

Email: Laurence.simonneaux@educagri.fr

Tel: 0033561753236 Fax: 0033561750309

The authors are members of a research team on SocioScientific Issues in education. It is an interdisciplinary team (physics, chemistry, biology, economics).