The Challenges for Science. Education for the Twenty-First Century
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THE SCIENTIFIC EDUCATION OF CITIZENS

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This paper attempts to show that the best answer to the challenges of science for the Twenty-first Century lies in the scientific education of the citizens. The education of future scientists and engineers to prepare them for their job is, of course, crucially important and has to be improved. The papers of this workshop were right to emphasize this point, to highlight the difficulties and to give some interesting suggestions. Such improvements are necessary. But I am not sure that they would be sufficient to meet the present challenges of science. I think that a scientific education for the citizens should not be just a diluted form of the education given to future scientists. In order to express the main theme of this paper, I will consider, first, the present challenges of sciences, then, the place and the character of science within a modern culture and, finally, the third and principal part of this contribution, how to achieve this scientific education for citizens and who would be involved in such a project.

THE PRESENT CHALLENGES OF SCIENCE

It is not necessary to emphasize again what has been told clearly many times, the last few days: science has been one of the most important factors in the evolution of our world for at least three centuries. For people it has provided new knowledge and for societies, many new possibilities of action which have made the life of the people easier. The speed of this change and improvement of conditions has been steadily increasing, especially at the present time with the appearance of what is called today modern technology. That is the art of building new machines, systems or equipment with fantastic performances by application of many new scientific results of var-

ious fields, especially through communication and computing sciences and techniques. This explosion of new products is developed by the market and what is called the new economics. This process will probably continue.

For any nation, the first challenge is to survive and, consequently, to develop its own ability in science and technology through effective education of its future scientists and engineers. However, it is not an easy task for many reasons. One major problem is the 'brain drain' which incites bright young people to do their advanced studies and to work in a country which offers better conditions that those they might get in their native land. We must also confess that at the present time, science and technology appear less attractive than they were in the past. In particular a gifted boy or girl may generally find today a more gratifying job by becoming a good lawyer or a good manager. Another reason is that science and technology are becoming more complex. Even a scientist cannot have a very precise idea of the scientific fields which are not close to his own domain of competence. Moreover at this time, the ordinary citizen doesn't understand what the scientists and engineers are doing. A social fracture appears between the people involved in the progress of science and technology and the other citizens. In the past, it was clear for most of the people that science and technology were working for the benefit of mankind. Today, it is not so obvious. The citizens see the damage caused to the environment by some modern industries or by certain new methods of modern agriculture. The globalization of the economy which is generated by the worldwide application of scientific achievements sometimes has had very serious social or ethical consequences. Moreover, the advances made by miniaturization thanks to electronics open up to terrorists the possibility of using chemical and biological arms. The people are frightened and sometimes get made. Finally, recent progress gives humanity the possibility to influence or reorient or modify its future. But who will be able to make the choice of what to do? Science alone cannot do this. That is why it must be deep-rooted in the overall culture.

Science within culture

It is clear that science provides new knowledge by processes very different of those, which are involved in many other disciplines; in particular those which belong to what are called 'humanities'. It is the reason why it is often found convenient to admit the existence of 'two cultures'.

We will not follow this view. We will consider that any body of knowledge and inventions belongs to culture if it might help a human being understand himself and understand, enjoy and make beneficial his relations with his physical and social environment. With such a conception, science obviously belongs to culture. But it remains to analyze and to clarify its place and role within culture.

Let us first consider the statements emanating from the classical sciences mathematics, physics, chemistry, astrophysics, geophysics and biology. They will be called scientific statements. The proof of such a statement – a theorem in mathematics, a law in physics or in chemistry, the existence and the properties of the cell in biology – when given by a professor in a lecture in front of students or by a scientist in a paper published in a scientific journal – is completely independent of the political, philosophical or religious views of its author and of his nationality. That means that all the scientists, if they are in agreement on the starting assumptions of the reasoning or on the conditions of the experiment, will agree on the conclusion. That is why one may say that such a statement belongs to the 'world of complete agreement'.

It is then quite evident that it is impossible, strictly speaking, to derive any philosophical or ethical conclusion from statements which belong to the 'world of complete agreement'. Nevertheless, that has been done sometimes in the past, and, as that world is ever increasing, it was thought that, in the future at any rate, the other kinds of statement would lose their validity. Even now such a temptation has not completely disappeared. An ideology may claim to be the sole global conception compatible with the world of complete agreement and, then, on the strength of this claim, it might disable the validity of a traditional culture, any other conception of humanism or a philosophical or religious belief. That was the case with the communist ideology in the Soviet Union. Is it not the case today with some capitalist conception?

What is clear is the increasing interactions of sciences and technology with social, political and ethical situations and problems. Great efforts have been made in order to introduce scientific methods and reasoning into the treatment of such problems. As a result, one finds in a modern culture human sciences, social sciences, law sciences, historical sciences and political sciences. However the 'scientists' working in these fields reach conclusions which have not in general the same kind of validity as those obtained by the classical sciences because the personal view or opinion of their author affects them. Nevertheless, they are very useful for the decision-

makers and cultivated people who want to increase the information available to them and stimulate their thought.

When science and technology come into interaction with a culture, they induce changes in this culture, some of which may be profound, but the foundations of the culture are not necessarily affected. It is important that the culture offers the possibility in any situation of keeping a critical standpoint to discover what is scientifically valid and what depends on a personal opinion or belief.

Means of providing scientific education for the citizen

In the first section it was shown that, in order to face its challenges in the present century, science has to be deep-rooted in overall culture. In the second, that in any situation faced by the society, the culture of this society must offer it the possibility of deciding what is appropriate for scientific analysis and what is not. The best means of satisfying this requirement is to provide every citizen with a suitable scientific education. This last section aims to indicate some ways towards reaching this goal. Three points deserve to be considered: what the pupils and students have to gain; the contributions of teachers; the contributions of scientists.

Advantages for the pupils and students

The most important element out of all the instruction they must receive is training to recognize the specific character of a scientific statement. This training might favorably start in the primary school with simple experiments children can do themselves. If one asks them to write the properties they have found or the result they have obtained, they will immediately note that it is completely independent of their age, their nationality, whatever they live in a city or in the countryside. The initiatives of my colleagues of my Academy Georges Charpak, Yves Quéré and Pierre Léna who lead up the operation: 'la main à la pâte' show that it works very well. When they are in junior high school – a secondary school – they will see, with some very simple examples, what is a proof in mathematics and what is a physical law. For those who want to enter a professional career which does not require an extensive education in science or engineering it is not necessary to give them too many statements of theorems or laws they will soon forget But it would be good for them to

get an idea of what science is and of is its place and role in the culture, in a Western culture and in other cultures, in China for instance. That implies they may receive some elements of the history of science. There is some chance they will recall that science has a history, that it is a conquest of humanity, that it was developed for the benefit of mankind. It would be good also if, during their schooling, they could see examples of some contemporary places devoted to sciences and technologies by visiting laboratories, factories and science-museums. It is essential that all these activities be led by the science teachers, under their responsibility and with their comments.

The teachers' contribution

Teachers in sciences in high school receive a special education to obtain the necessary knowledge in the field they will have to teach and also a training to develop their teaching ability. They are selected by some process which check that they have the required capacities. That is good. That is necessary. Is it sufficient? In many countries the answer is affirmative. But, if one agrees with what was said in previous sections, it is not. Future teachers must receive in addition some elements of the history of sciences, even elementary ones, and must be prepared to increase their knowledge when necessary. Their attention must also be drown to the importance of the interactions of scientific and technical developments with many modern problems of society. These complementary additions to the program of the purely scientific disciplines are useful to provide future teachers with the sound resources needed to fulfil their job. Of course, it is a controversial point which deserves to be discussed. The position taken in this paper is that the scientific education has to be given by a teacher of science who must receive everything that might help him to convey to any of his students a correct conception of science so that he or she might be an enlightened citizen. It is highly desirable that this teacher makes the teachers of the other disciplines aware of what he is trying to do in order to obtain their agreement and perhaps their support.

The scientists' contribution

Scientists must, of course, firstly feel concerned by all that might be done towards providing citizens with a good education and be ready to contribute to the operations undertaken for this goal. They may con-

tribute to the education of the teachers of science, be aware of the problems and difficulties they encounted, and give them help and support. They can make suggestions which may be useful.

But they must also understand that if science today does not attract enough young and bright people, it is because public opinion has lost the confidence it have in the past. The arguments for science which worked a few decades ago do not now have the same impact. It is up to the present scientists to discover the new formulation of the scientific ideal, one which will be more appealing and fit present expectations. It seems to me that it would be necessary to assert and to prove the relevance of fundamental research to modern society, as did the report of ALLEA – the association bringing together the European Academies of sciences and humanities – in 1996. Scientific statements are universal. The interpretation which can be given to them depends on the culture of the society where they are received, in particular on its ability to take on board new results without losing its basic values. Consequently, scientists are encouraged to participate actively in the cultural life of society. That will make education of the citizens easier and more successful. As it was noted by some of you, Academies have a special duty in this respect. As it is written in the statutes of the French Academy of sciences, the Academy must work in order that the cultural values of sciences may be integrated in every human culture. Let us note also that such a scientific ideal is necessary if one wants to avoid domination of scientific activity by industrial and commercial forces.