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ABSTRACT

This report of the third session of the International Commission on Education for the Twenty-First Century describes the two main items on its agenda: the teaching of the sciences, and the production of knowledge, mentioning in this connection the particular role of the universities. From these debates and deliberations arose a number of central ideas that provided a framework for the suggestions concerning these two items. The three central ideas from the debate on education and science included: (1) questions on the meaning of science; (2) the amgibuous role of science with regard to cultures and societies; and (3) science as a factor for individual evolution. The teaching of sciences is discussed. Education must arrange two approaches to science: (1) the learning of curiosity about the natural and technical environment; and (2) access to mathematics, which is both an instruction in logic and a way of expressing the world, particularly for the 21st Century, where the things that science deals with are increasingly abstract and invisible. The prior condition of access to mathematics is command of language. The report distinguishes between four levels in the teaching of science, which, though interdependent, are covered by different recommendations: (1) basic or primary education for children; (2) secondary education; (3) higher education, of which universities are only a part; and (4) continuous education or the popularization of science for adults. Central ideas on the production of knowledge and the multiple role of universities and higher education in general include: (1) the development of the different sciences; and (2) the future of scientific and university systems. (DK)

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U N E S C O

International Commission on Education for the Twenty-First Century

Third Session
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Report on the study: Education and science

INTRODUCTION

The third plenary session of the Commission was held in Paris from 12 to 15 January 1994, and was preceded and prepared by a working group (10 and 11 January) consisting of several members of the Commission and experts from different parts of the world (see annex).

During the session itself, five hearings gave members of the Commission an opportunity to question eminent scientists on the two main items on the agenda: the teaching of the sciences, and the production of knowledge, mentioning in this connection the particular role of the universities.

From these debates and deliberations arose a number of central ideas, which provided a framework for the suggestions concerning these two items:

1. The central ideas from the debate on education and science

1.A. Questions on the meaning of science

Exacting in its methods, directed towards knowledge, and attractive through the joy it brings, science is regarded by everyone as one of the most fulfilling activities for both individuals and society, particularly since, in its pure form, it appears immediately as a collective asset. The knowledge "discovered" by the scientist is an immediate addition to humanity's heritage of knowledge, and becomes a symbol of universality. At the same time, the history of science reveals the relativity of each discovery, so that it can be considered as a sort of antidote to all forms of "fundamentalism".

However, the discussions set a number of limits to this very scientific and Europe-centered assertion.

i) a philosophical limit: truth and knowledge can, and doubtless should, be sought in many different ways, including through spirituality, religion and art, so that the human being can develop to the full. Avoiding the temptation of a sort of scientific totalitarianism, or scientism, we must remember that scientific knowledge does not constitute truth, even though one person's discovery may become a universal law, but is only a milestone in the continuous process of trial and error, refutation, and further experimentation. The humility of science in no way contradicts its ambition for progress.

ii) an ethical limit: science, which has become increasingly applied in practice, is in danger of being used as an instrument of domination, an instrument of power over things and people, and as an instrument of people's death.

iii) a geopolitical limit: as it becomes increasingly complex and increasingly expensive, science becomes less and less accessible to those deprived of resources, whether material or intangible. The "knowledge gap" is constantly widening between the major scientific centers and the least developed countries (Africa, and, to a lesser degree, South America). Though science is indeed a source of development, particularly by virtue of the technological advances it makes possible, it may well be increasing this gap rather than helping to close it, to say nothing of its consequences for the environment, which are very unequally distributed.

B. The ambiguous role of science with regard to cultures and societies

Science is synonymous with modernity and, as such, occupies a particular place among the driving forces of society. It is widely recognized to be a source of material and symbolic power capable of producing perverse effects, since its universal nature is a permanent challenge to particularism and tradition. However, everyone also recognizes that science opens up incomparable prospects for development. Science must preserve a balance, specific to each society, between the cultural past and the unpredictable future. Indeed, as a search for the spatial and temporal transcendence of established knowledge, it also constitutes a challenge to custom and learning and is a carrier of cultural revolution. If imported or appropriated by a poorly-integrated elite, it therefore runs the risk of being rejected. The perception of the role of science and scientists is thus decisive for the establishment and development of a scientific culture and for the teaching of science. These may be obstructed if, for example, science is viewed as being too "Western", or as a luxury compared with daily necessities, or again, as something undesirable and hostile to the cultural heritage. In this case, science is in danger of being troublesome rather than useful, because inappropriate, and of bringing only the social costs of modernity.

However, as a basis for solving problems and efficient action, it is sought by society to provide a foundation for the development process. As such, both its "natural science," and its "human and social sciences" dimensions can be of use.

Transcending the contradiction between the specific and the general, and between tradition and futurology, raises the central question of the spread and the appropriability of science. Perhaps it is necessary to distinguish between the universality of knowledge as reserved for the international community of scientists ("Big Science") and the specific character of its applications (although the present production of fundamental knowledge appears with increasing frequency to be put to specific use, and therefore difficult to distinguish from "applied" science).

C. Science as a factor for individual evolution

There are two aspects to consider. First, that of the broadening of knowledge, which enables all of us to better understand our environment (increasingly full of science and technology), and secondly, that of the shaping of an inquisitive and critical mind, enabling us to remove the mystery from the real world and acquire independence of judgement. Science should therefore allow every human being to walk a path that is illuminated by the joy of understanding, and that is a responsible path through that person's capacity to act on his environment in an informed way. From this point of view, the teaching of the history of science should be encouraged, not only as a way of learning science itself, but also as an introduction to responsibility and even to citizenship.

From this there followed an immediate and unanimous recommendation: all children should be able to have appropriate access to the scientific approach and become "friends of science" for the rest of their lives.

II. The teaching of sciences

Each of the scientists questioned seemed aware of the fact that teaching in general, and the teaching of science in particular, is part of an extremely fluid and unstable world. It is no longer possible to have a linear view of development, even on the scientific level, and as a result, a large number of certainties concerning education have become null and void. The teaching of science can thus only acquire meaning by being rooted in a family and cultural heritage. The scientists' general concern may therefore be expressed as follows: how can we make science accessible at all levels and in all places? How can we ensure that everyone, regardless of age or living conditions, can acquire a scientific approach?

Education must arrange two approaches to science. Firstly, there must be the learning of curiosity about the natural and technological environment and secondly, there must be access to mathematics, which is both an instruction in logic and a way of expressing the world, particularly for the 21st century, where the things that science deal with are increasingly abstract and invisible. However, it is unanimously accepted that the prior condition of access to mathematics is command of language.

Despite these two main gateways to scientific knowledge, the growing abstraction and complexity of the natural and life sciences poses a formidable problem for teaching and popularization. Is it necessary, for example, to abandon the teaching of modern physics or biology at the secondary level because they are too complex and too far removed from the tangible world?

For the sake of accuracy, we must distinguish between four levels in the teaching of science, which, though interdependent, are covered by different recommendations: basic or primary education for children, secondary education, which usually leads on to higher education of which universities are only a part, and continuous education or the popularization of science for adults.

II.A. The primary level

There is unanimous agreement concerning the need for a simple access to the scientific approach through curiosity about nature and the environment, the discovery of logical patterns by mathematics or other methods (enigmas in Africa), the learning of quantitative description and the approach to the concept of scientific laws by developing the capacity for prediction.

The main problem here seems to be the language of learning. When the native language is not one of the usual languages in which science is built up and passed on, a special effort must be made to ensure that the teaching of science does not mean a break with traditional culture. From experiments in Senegal with the teaching of mathematics in the local language, Professor Thiam was able to demonstrate that original methods specific to each culture may be used to help children acquire concepts and forms of mathematical reasoning in their own mother tongue.

Again, at this level, the approach to science should not be provided by specialized scientists but by general subject teachers capable of making the approach to science part of a comprehensive approach to knowledge and culture. Their training must therefore be particularly appropriate, ideally requiring much continuous education to ensure that the teachers themselves do not feel too cut off from scientific progress.

II.B. Secondary education

The experimental method should be the preferred approach to all sciences which lend themselves to it. It enables procedures to be employed for refuting hypotheses, and deriving benefit from errors, which is, in fact, the application of the scientific method. (A careful distinction must be made between the experimental demonstration, which leaves the student passive, and the true experiment, which teaches method but also stimulates curiosity and reveals the risks of the scientific approach.)

The problem here is the cost of experimental apparatus, priced more and more out of reach, even for schools in the developed countries, to the extent that the teaching of physics, for example, is becoming increasingly abstract, resembling a hybrid form of mathematics repellent to many students.

The remedy may possibly be sought in the pooling of experimental material by several establishments, or by courses for students in science laboratories, whenever this is possible. Several speakers nevertheless stressed the point that the priority in the matter of resources was the availability of well-trained and scientifically imaginative teachers rather than access to costly equipment, which, once bought, often remained unused for lack of competent teachers.

In secondary schools, the idea of science as a finished entity must be put under a critical spotlight, particularly by teaching the history of science, which shows the uncertain beginnings and branches of science, thus helping students to conceive of science as a method of thought rather than weighing them down with curriculum content. This brings us back to our earlier warning concerning the chief difficulty of teaching science, i.e. mastery of language.

At the first two levels, there is intense concern with the quality of teacher training. At present, teachers are too often trained in establishments where they have no opportunity of seeing science in the making and, at the primary levels, many teachers have received no training whatsoever in the natural sciences.

II.C. Higher education

On the strict level of science teaching, in other words the transmission of knowledge in the very place where much of it is brought up to date, the problem is both material (students must have access to documentation and high level scientific teaching, since science is largely international) and epistemological (students must be able to try themselves at the frontiers of science, which implies training in and by research and hence the existence of good research centers close at hand). However, the increasing flow of young people to higher education, in all countries of the world, is leading to a conflict between mass education and high-level scientific teaching.

Part of this difficulty may be resolved by a change of teaching methods. Team work, enabling the development of a balance between co-operation and competition, may lead to the emergence of "leaders" or "*primus inter pares*" who will become the scientific elite. In the same way, the tutoring of average students by more gifted students may increase the effectiveness of education and contribute to the cohesion of the university community.

In any case, wherever science is produced and taught, teaching must be project-based, like science itself. Finally, at this level even more than other levels, since this type of establishment must be the nursery for future scientists and teachers of science, the beauty of science, as well as the human and social responsibilities of the scientist, must be made clear to the students.

II.D. The spread or popularization of science in the non-academic and non-scientific environment

It is absolutely necessary to learn to live and even enjoy living with science and technology. The power they have for good and evil must be recognized, as must their limits. It is also important not to let oneself be simply dazzled by spectacular technology, but to understand the needs of fundamental science. The scientific approach, proceeding from an observation or specific fact to a scientific, and therefore universal, fact, must be made clear. Modern societies appear to be wide of the mark on all these points, even in the most developed societies, or the managing and political classes of these countries (the proliferation of "false sciences like astrology" is evidence of both fascination with the cosmos and the absence of any real introduction to astro-physics). Apart from the media, increasingly called on to be active in this field, and the museums of science and technology, some interesting local experiments must be noted e.g. voluntary associations for the popularization of specific subjects; "science pageants"; astronomy clubs; and "science boutiques".

III. The production of knowledge and the multiple role of universities (or more generally, of higher education)

The framework for the studying of the future of science and the action of institutions of higher education and research must be shaped by the major trends of the 21st century.

III.A. The development of the different sciences

Several major trends of the end of this century should draw attention to the difficulties encountered in maintaining the universal nature of science and getting it to play a positive role in the lasting development of individuals and societies.

- In the production of knowledge, the subject of research is becoming narrower and narrower and more and more complex as science advances. The result is hyper-specialization, which isolates disciplines and obscures the global nature of beings and systems. Higher and higher barriers separate the different branches of knowledge at the very time when the problems of present and future require an integrated approach. This interdisciplinarity that is needed also includes the human and social sciences.

- The complexity of the relations between science and technology.
  Rebuttal of any linear relation between science and technology challenges the idea that science is neutral, disinterested, and available to anyone capable of reading scientific reviews. In fact, in the natural and life sciences, which are used and financed by industrial societies, the two processes are often closely interlinked (there

is less risk in the case of mathematics, but it develops more slowly). The danger of science being taken over or managed by the major international firms, which care little for the well-being of the disadvantaged, is thus increasing the trend towards the monopolization of the products of science and technology and is embroiling science in economic power strategies, on a world-wide scale, which are contrary to its universal nature and blot out its characteristic as a "common good".

III.B. The future of scientific and university systems

Knowledge, even the most abstract knowledge, is currently perceived as the key to autonomous development in an interdependent modern society which is increasingly being shaped by scientific and technological progress.

Breaking away from the tradition of free and universal science, the question of the specific responsibility of education systems, particularly universities, in the production of scientific capital, is presently viewed from a utilitarian viewpoint. Indeed, whether in the attempt by the developed countries to free themselves from crisis, or in the attempt by the developing countries to "catch up", the search for knowledge that is "useful" for each country or each region, i.e. slanted towards the solution of the problems of that country or region and amplified by its own cognitive capital, is now something that is well attested. How can this process be given a greater impetus, however? The example of Africa seems to illustrate the internal contradictions threatening it. How can a scientific elite of international calibre yet oriented towards specifically African problems be trained when one knows what the systems for the international evaluation and circulation of research work are? What hope is there of limiting the perverse effects of the "brain drain" when one compares the conditions of scientific work in the countries of origin with those in the countries of adoption? How are sparse university financing and small numbers of good teachers to be shared between mass education and the training of such elites?

Although the problems of the "knowledge gap" seem to have become less critical, if we discount sub-Saharan Africa where a whole series of difficulties (demographic, political, logistical) are concentrated, all countries are now asking similar questions about the future of universities. What kind of institution can provide a response to the different tasks assigned to higher education and research? How can the balance be maintained between research, the training of skilled personnel (including teachers) and the preparation of responsible elites?

Neither the example of the Arab universities, which passed on knowledge and trained elite groups, nor that of the European university of the Middle Ages, intended above all as a community, nor that of the Humboldt-style university, seeking the truth, can meet the expectations entertained about the modern university. Certain countries apart (the Eastern bloc, for example), where the production of science and the transmission of knowledge have been institutionally separated for various, sometimes political, reasons, it is generally considered that the production and transmission of knowledge should be as closely integrated as possible, for the very vitality of science. On a practical level, however, the application of this principle often runs into the contradiction between mass education and higher education.

Higher education is in fact subject to a growing and diversified quantitative demand, for several reasons:

Firstly, knowledge is gaining in importance over material resources as a development factor. The growing role of scientific and technological knowledge is demonstrated by the spectacular impetus it gives to industrial activity and economic exchange, and by the solutions it offers for the problems of human development (nutrition, life expectancy, health, living conditions, communication, access to culture).

It seems that there is a growing need for the production and circulation of knowledge in all fields.

Secondly, economics, gripped in this way by technological innovation and progress, are becoming increasingly demanding in terms of manpower skills. In all sectors, the structure of employment is becoming distorted as societies progress and as machines replace manpower. The numbers of production staff are falling as tasks of inspection, operation, and organization are on the increase, expanding the need for mental abilities in staff at all levels. Universities and, in a wider context, the systems of higher education, are therefore increasingly required to provide vocational training that matches these developments.

Finally, in this society of knowledge, the functions of education and training are becoming strategic. The length of schooling tends to be growing everywhere, and lifelong training appears to be increasingly necessary. A growing number of people will therefore be needed to take this task on, and even though not all of them may be trained specifically as teachers, since they will no doubt have to be both teacher and student in turn, it is clear that the principal resource center for the initial and further training of these teachers will remain higher education, as the place where knowledge is brought up to date.

It therefore seems legitimate that, everywhere in the world, strong social demand is being brought to bear to develop this sector of education and that, as a result, the numbers of students in all countries are increasing considerably (at the global level, the number of students has more than doubled in 20 years, increasing from 28 million in 1970 to more than 60 million today).

However, in meeting this demand, systems either try to respond to all demands and adapt their resources to them, quantitatively or qualitatively, or attempt to combine selective entrance to certain establishments with a variety of institutions. In both cases, it is extremely difficult, although necessary, to pursue the objective of selecting the best students for science, and the objective of qualification for all. No-one wants to give universities the exclusive function of vocational training. No-one challenges the particular responsibility of universities and academics in the construction of the identity and future of societies, over and above strict economic growth. The emergence of elite groups capable of participating in the strategic decision-making processes of their own countries or regions and, more generally, in building up the capacities of the least-developed countries, are thus major issues in university policy, as the Pacific countries have realized.

From the work of the Commission, a series of recommendations thus emerged:

- In order to reconcile the international criteria of scientific quality with the necessity of rooting the progress of knowledge in the different cultures, the formation of research partnerships and networks must be encouraged worldwide and evaluation procedures must be applied to stimulate high standards everywhere.

  Considering the growing advance of certain countries in scientific matters, the destructive effects of the "brain drain" and the perverse effects brought about merely by importing scientific information, in each country or region should be set up the minimum necessary infrastructure of scientific resources to permit circulation, for the good of all, of knowledge produced throughout the network; this could perhaps be done with international aid (the redemption of debt for example). In other words, "brain circulation" should be substituted for the "brain drain".

- Developing an individual and collective sense of responsibility within the scientific community seems crucial in order that the economic aims of research do not cause further world imbalances, and do not overshadow the humanitarian missions and ethical questions raised by the progress of science and technology.

International Commission on Education for the Twenty-first Century

Working Group on Education and Science
10 - 11 January 1994

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