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**"Scientific progress and science teaching: Basic knowledge,
interdisciplinary methods and ethical problems"**

Problem note for organizers and speakers

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Introduction

The purpose of this note is to outline some of the current problems and developments of science teaching¹.

The note consists of three parts. The first part deals with changes in the contents taught. The main factor here has been the increased linkage between school and society, the effect of which has been to make contents less abstract, more practical and more up to date. This development is occurring as part of a broader process, in which firstly knowledge and science are playing an increasingly decisive role in the development of society and in everyday life and, secondly, the rate of school attendance in general is tending to increase in the world, making it necessary to adapt contents to mass education, directed at different types of learners.

The second part deals with changes in teaching practices and the role of the teacher. The updating of contents and the expansion of knowledge have made it even more necessary to master sufficient abilities, know-how and methods, to the extent that increasingly curricula are adopting as their objective the acquisition of more transversal skills, which are more subject to evaluation, but less knowledge². On general issues concerning education and teaching methods, reference may be made to: "Educating and Training³", "Learning⁴" and "Learning ... yes, but how⁵", and on the sciences: "A teaching method for experimental sciences⁶" and issue No. 19 of the journal Aster⁷.

The third part will look in more detail at some tools, skills and themes which science has in common with other disciplines.

1 The question of contents

1.1 Basic knowledge

With the discovery of new scientific and technical knowledge, which must at least in part be incorporated in curricula, educational systems are faced with a dilemma: how can the new

¹ Ever since it was founded, one of UNESCO's main concerns has been science and scientific education. In 1999, the World Conference on Science in Budapest adopted a "Declaration on science and the use of scientific knowledge", some extracts of which are given in the annex on page ...

² One example is the English programmes, mentioned in an internal note to the Ministry of Education of the Province of Quebec, Canada, March 2001.

³ Ruano-Borbalan, Jean-Claude, dir. "Eduquer et Former - Les connaissances et les débats en éducation et en formation" (Educating and training - Knowledge and discussions concerning education and training), Editions Sciences Humaines, France, 1997.

⁴ Giordan, André, "Apprendre!" (Learning!), Collection Débates, Berlin, France, 1999.

⁵ Meirieu, Philippe, "Apprendre ... oui, mais comment" (Learning ... yes, but how), Pédagogies outils, ESF éditeur, France, 1999.

⁶ Giordan, André, "Une didactique pour les sciences expérimentales", (A teaching method for experimental science), guide Belin de l'enseignement, Belin, France, 1999.

⁷ Revue Aster - Recherches en didactique des sciences expérimentales, no. 19, "La didactique des sciences en Europe" (Science teaching in Europe), INRP, France, 1994.

material be added to course timetables which if anything are getting shorter? Clearly something has to go, but what?

Given this situation, there are two possible solutions: some knowledge is indispensable because it is timeless and because it provides a base on which all other useful knowledge may be constructed at any time, provided that the necessary sources of information are available. This is what may be termed "basic knowledge". This basic knowledge must then be supplemented with the acquisition of the ability needed to seek and process information, which allows the learner to become integrated within his environment and to find the answers to any questions that may arise. This is probably one of the reasons why the acquisition of methodological skills has become so important in the last few decades.

According to that very simple definition of basic needs and knowledge, one might consider that there are three basic skills, namely "reading, writing and counting", and that starting from them everything else can be added. Of course the real situation is much more complex.

With regard to skills of a methodological nature, as we shall see below, a certain know-how is indispensable over and above the three basic skills mentioned above. Moreover, since there is no means of drawing a clear distinction between form and substance, skills cannot be acquired in a vacuum without reference to something tangible; real objects are needed on the basis of which the skills can be developed. Also, with the gradual spread of mass education in all countries, that is, education affecting an entire age bracket, the idea that intellectual skills should be constructed in abstract worlds, like mathematics, on the assumption that once they have been mastered they can be applied to all other types of knowledge, is a dangerous oversimplification that takes no account of the diversity of learners.

Every society at some stage has probably demanded that a certain quantity of knowledge, resting on a hard core of basic understanding, should be shared by all children when they leave school. In order to identify these requirements, most countries set up ad hoc committees in charge of establishing a corpus of necessary knowledge, either defined very precisely and in great detail, like in the French programmes, or aimed at the acquisition of more general and less specific skills, as is the case with American "standards".

One way of spotting general trends consists in comparing the contents of the programmes, standards or curricula of different countries.

If we compare the contents of science programmes in England, Belgium, the Canadian provinces of Quebec and Ontario, and the state of Vermont in the United States⁸, we find that they all have the following subjects in common:

- Living beings
- Matter
- Energy
- The universe, space, Earth, environment.

Other subjects are found in two or only one of the cases:

- Science and technology in human activity;
- Air, water and soil;
- Techniques and instruments;
- The history of life and sciences.

⁸ Internal note to the Ministry of Education of the Province of Quebec, Canada, March 2001.

Then, more unusually, there are odd subjects such as "The logic of science and technology" (Quebec) or "scientific gestures" (England), which probably relate more to methodological aspects.

1.2 The impact on society of the development of science and technology and its effect on education contents

More than any other period of human history, the twentieth century was profoundly affected by the development of science and technology.

There is no doubt that the dominant discipline in the first half of the twentieth century was physics. At the end of the nineteenth and the beginning of the twentieth century, atomic theory was finally accepted as the key to understanding the structure of matter. Further discoveries of the time were radioactivity, the theory of relativity and the quantum theory. Those major discoveries set in motion a process of development that lasted for the whole of the twentieth century, producing an impact on new materials, electronics and many other fields to which they lent inspiration. As Caro⁹ has pointed out, physics domesticated steam for engines, then the electron and then the photon. In the second half of the twentieth century, it was more the life sciences that caught the limelight. With developments in instrumentation and biochemistry in particular, the life sciences changed their status from that of natural or observational sciences to experimental sciences. The crucial event for this revival of the life sciences was almost certainly the description of the molecular model of DNA by Watson and Crick in 1953, which led to the development of biochemistry and genetics and to spectacular progress in medicine. Finally, the development of computing (bearing in mind that the first electronic calculator, ENIAC, was manufactured in 1946) constituted a third major period in the history of science and technology of the twentieth century. Computers spread throughout society from the 1970s onwards and, in 1989, the development of networks, after the multimedia, opened the way to Information and Communication Technologies, whose impact is still being felt at all levels of society.

Alongside that sequence of periods, each of which was dominated by a particular scientific or technical field, two very important developments took place in the second half of the twentieth century. The first was the considerable increase in the specialization and diversification of disciplines. Combined with the emergence of the related forms of jargon, this had the effect of widening what many authors referred to as the "gulf" between the scientific community and the rest of society. The second change was the growing interpenetration between science and technology and between basic research and applications. The impact of science on all sectors of society was further increased as a result and a greater urgency was added to the issues of science funding and the social debate concerned with research.

This gave rise to a great deal of questioning between science and society, leading to new demands by citizens and a need for new educational contents.

Issues of citizenship were moved to the forefront, while consternation was expressed at the common state of "scientific illiteracy". This illiteracy is not as obvious as might appear at first sight. While it may be surprising to find that 55% of Americans believe that the Sun revolves around the Earth, it is worth considering what sort of questions are useful and what questions people want answered. Very often, the criterion for scientific and technical culture is taken to

⁹ Caro, Paul, "La roue des Sciences" (The wheel of science), Albin Michel, France, 1993, Chapter VI.

be "academic" knowledge, although people's doubts and queries are more practical and more down to earth. Measured by those criteria, the scientific illiteracy test would certainly turn out more favourable.

This shift in the focus of interest is quite well illustrated in two opinion polls (the first, commissioned by the CNRS (National Commission for Scientific Research), by Suzanne de Chevigné, Laboratoire Politique et Communication, 1999, and the second ordered by the Ministry of Research in November 2000¹⁰). The polls show quite clearly that the concerns of French people can be ordered into three groups in decreasing order of importance:

- matters of personal interest affecting people surveyed individually (health, environment, etc.);
- matters relating to the governance, organization and operation of research;
- matters related to pure knowledge.

This order of priorities and the appearance of governance aspects are new factors to emerge from the opinion polls.

Education has followed a somewhat similar line of development. On the one hand its main role is to prepare people to live, to become socially integrated and to play a responsible part in a community which is reasonably homogenous in cultural terms. On the other hand in a globalized society it trains people and prepares them for an occupation or rather for varied professional activities. It is for these two reasons that educational contents must to some extent be based on reality and current events and that school education is coming more and more into contact with the rest of society.

1.3 The role of institutions offering non-formal education and out-of-school resources

One way of opening up school education to society is through scientific institutions and resource areas. These are areas out of school that portray science, technology and nature, that is, science and technology-oriented centres, general museums and science museums, and research enterprises and organizations (provided that some mediation service is available), as well as nature discovery areas and parks.

Apart from the fact that they bring students into contact with real objects or "artefacts" which are different from those used in class, and with mediators and professionals, these areas offer other benefits which should not be overlooked:

- The present physical environment requires a change in the teacher's attitude and professional practice. He is in an environment where the "frontal" teaching method has become inappropriate and where the density of resources and information is such that special attention has to be given to allowing students more independence in research, either alone or in groups.
- The student is placed in a particular physical and relational environment (with other students, teachers and mediators) and has to deal with information that carries personal and day-to-day implications that may be more powerful than in the classroom; this in turn may give rise to a greater "appetite" for knowledge.

¹⁰ Mentioned by Michel Demazure, President of the Cité des Sciences et de l'Industrie, in the course of a talk given on 8 December 2000.

- The relation between mediator and learner has changed as part of a new social relation involving different components, such as exchanges of knowledge¹¹, or the behaviour of a student or apprentice in relation to a teacher, tutor or master¹².

There are many works that deal with these matters in some detail. One example is an issue of the journal "Aster", dealing specifically with out-of-school resources, chiefly museums and especially natural science museums¹³. Other specific cases (those of an agronomic farm in Israel and an environmental study network in Norway) are analysed in a publication directed by John Leach and Albert Chr. Paulsen¹⁴. The book by Goery Delacôte, Director of the San Francisco Exploratorium, illustrates well how the educational system can take advantage of innovations produced by science museums¹⁵. Lastly, Jack Guichard and Jean-Louis Martinand set out the theoretical foundations of research combining mediation in museums and classroom teaching, while giving a good description of exhibitions' impact on learning¹⁶.

1.4 Teaching disciplines

In general in this note we deal with know-how and transversal knowledge. From the point of view of research, discipline-based teaching builds up a corpus of specific knowledge related to the characteristics of individual disciplines.

Two works may be mentioned in this respect: "School knowledge and the teaching of disciplines"¹⁷ and issue No. 27 of Aster¹⁸.

¹¹ The association movement "Réseaux d'échanges réciproques de savoirs" (Knowledge exchange networks) is particularly interesting in this respect; see: Héber-Suffrin, Claire et Marc, "L'école éclatée" (The open school), épi, France, 1994.

¹² Delacôte, Goéry, "Savoir Apprendre - Les nouvelles Méthodes" (Knowing how to learn - The new approach), Editions Odile Jacob, France, 1996, Chap. 4.

¹³ Girault, Yves, ed., Revue Aster - Recherches en didactique des sciences expérimentales, no. 29, "L'école et ses partenaires scientifiques" (The school and its scientific partners), INRP, France, 1999.

¹⁴ Leach, John; Paulsen, Albert Chr., "Practical Work in Science Education - Recent Research Studies", Kluwer Academy Publishers (Denmark), Roskilde University Press (the Netherlands), 1999, Section 4.

¹⁵ Delacôte, Goery, op. cit.

¹⁶ Guichard, Jack; Martinand, Jean-Louis, "Médiatique des sciences" (Science media), collection éducation et formation, technologies de l'éducation et de la formation, Presses Universitaires de France, France, 2000.

¹⁷ Develay, Michel, "Savoirs scolaires et didactiques des disciplines - une encyclopédie pour aujourd'hui" (School knowledge and the teaching of disciplines - an encyclopaedia for today), collection pédagogies, ESF éditeur, France, 1995.

¹⁸ Rumelhard, Guy, Coord., Revue Aster - Recherches en didactique des sciences expérimentales, no. 27, "Thèmes, thèses, tendances" (Themes, theories, trends), INRP, France, 1998.

2 The question of methodology

2.1 Experimental practices, in touch with reality

As we saw above, greater emphasis has been placed on methodological skills and know-how as a result of the exponential growth of knowledge. This is true of science and technology for this reason, but even more so because action in science and technology depends to a large extent on a way of thinking, a strict approach and a frame of mind.

One of the main methods used in science is the so-called experimental method. All too often in French there is a tendency to confuse experimentation (“*expérimentation*”) with practical work (“*manipulation*”). Practical work, especially with real things, is no doubt essential, but not sufficient for experimenting.

The experimental method follows the steps listed below.

Statement of a question concerning a phenomenon or object

Construction of a hypothesis regarding the answer to the question

Establishment of an experimental protocol for checking the hypothesis against the facts

Implementation of the experimental protocol

Analysis of results, discussion and conclusion invalidating or confirming the hypothesis

If necessary, repetition of the experimental protocol to ensure that the same result is repeated

Or else

Statement of a new hypothesis, unlike the previous one, and reinitiation of the experimental process

Diagram illustrating the different stages of the experimental approach

This need to renew contact with real facts, which is all the more important in view of the need to adapt excessively theoretical and "frontal" course material and in view of the need to develop ICTs (though these should not monopolize the information media offered to students), is clearly illustrated in the new programmes based on this type of approach.

In France, since 1996, an experiment has been tried along these lines in primary education. The programme is called "La main à la pâte" (roughly "Hands on"), which was launched by the physics Nobel prize winner Georges Charpak. It was a follow up to the work carried out by Leon Lederman, physics Nobel prize winner in the Chicago schools in the early 1990s¹⁹.

This programme, the key feature of which was the introduction of the experimental method, led to some particularly interesting side-effects:

- It brought scientists and students into the classroom, which had the effect of renovating the teaching relationship with pupils, and probably at the same time provided teachers with some extra science training in a non-formal context;
- It gave the pupils greater responsibility, as they had to conduct their own experiments and enter their results in an experiment log-book;
- It generated considerable inventiveness on the part of the teachers who followed the approach and who subsequently reported the results of their work on the Web²⁰.

Projects involving experimental methods based on research activity are also described in John Leach and Albert Chr. Paulsen²¹; others, with greater emphasis on cooperation and interactions between pupils, are described in WM Roth²².

¹⁹ This project, "La main à la pâte", is described in two works:

Charpak, Georges, pref., "La main à la pâte: les sciences à l'école primaire" (Hands on: science in primary education), Flammarion, France, 1996.

Charpak, Georges, ed., "Enfants, chercheurs et citoyens" (Children, scientists and citizens), Editions Odile Jacob, France, 1998.

²⁰ The resulting database is available on the website www.inrp.fr, which is related to a particularly active mailing list.

²¹ Leach, John; Paulsen, Albert Chr., "Practical Work in Science Education - Recent Research Studies", Kluwer Academy Publishers (Denmark), Roskilde University Press (Netherlands), 1999, Sections 1, 2 and 3.

²² Roth, Wolff-Michael, "Authentic School Science - Knowing and Learning in Open-Inquiry Science Laboratories", Science & Technology Education Library, Kluwer Academic Publisher, Netherlands, 1995.

2.2 Some aspects drawn from recent research into teaching methods and innovations

2.2.1 Making the learner act

Making the learner more active is a goal of many educational theories, as a means either of improving or of facilitating learning. One very good example in this respect is Piaget's constructivism. Many of the works mentioned in the bibliography involve giving the student an active role to play.

2.2.2 Diversifying learning paths

It is quite natural to recognize that every student needs to follow his own learning path if one admits that he must be the main actor in his learning process. The new education movements that developed in the first half of the twentieth century (e.g. Freinet, Decroly or Montessori) strongly emphasized this need for adapting learning paths more to the individual.

2.2.3 Taking account of initial representations

The active role of the student and the personalization of his study course also depend on recognizing that the starting point is not the same for everyone. On any given study subject, the student's prior knowledge or ideas (referred to by some authors as the "initial representations") have to be known before the teaching course can be determined. Thus learning is conducted in a changing environment and is continually affected, like the brain in which the process takes place, by changes in that environment. This is what some Anglo-Saxon authors have called the "allosteric learning model", later rendered in French by André Giordan as "modèle allostérique", by analogy with molecular structures that change according to the environmental conditions in which they are placed²³.

2.2.4 Knowledge about knowledge

This is how André Giordan describes what most authors refer to as "metacognition"²⁴. Once the learning process has been completed, the facilities and difficulties encountered during the process must be discussed with the learner. This will be a way of validating and strengthening independent skills in relation to information, so that a formal reconsideration of the practices improves the learner's performance on new subjects²⁵.

2.2.5 Project-oriented teaching methods

Using projects in teaching is probably a good way of increasing the pupil's involvement. The advantages of the method are that it:

- Shares the work intention and objective with the students;
- Facilitates a very general approach to work, which is multidisciplinary and may even involve some logistics, depending on the project;
- Diversifies the stages of activity, starting with preparations, followed by the project itself and then its explanation, dissemination and further use.

²³ Giordan, André, "Apprendre!" (Learning), Collection Débats, Belin, France, 1999, p. 14.

²⁴ Giordan, André, "Apprendre!" (Learning), Collection Débats, Belin, France, 1999, ch. 11.

²⁵ See Meirieu, Philippe, ed., "La métacognition, une aide au travail des élèves" (Metacognition, a working aid for students), ESF, France, 1999.

2.3 Documentary research

Documentary research involves a whole set of specific technical skills. The main stages may be summarized as follows:

- Stating a question;
- Identifying a combination or combinations of key words which will lead to sources of information needed for the reply to the question;
- Selecting sources according to several criteria (country, date, author, publisher, references, etc.);
- Studying the sources through their contents, indexes, etc.;
- Summing up the collected information.

This activity requires a variety of important skills:

- Mastering the actual research know-how;
- Adopting a critical approach to the documents collected (author, publisher, reference, comparison with independent sources of information, etc.);
- Producing a summing up.

It is worth noting that this documentary research practice, which is designed with the book "medium" in mind, can and should be used in other information environments. Examples include resource centres offering information in different forms (such as science centres and science museums) and digital resources available on networks, such as the World Wide Web.

2.4 A learning approach adapted to science teaching

The experimental approach and aspects of teaching methods mentioned above require the implementation of specific teaching sequences. These are of different sorts according to the disciplines involved, students' standards and the topics dealt with. Some sequence structures can nevertheless be used to prepare class activity and may even be included in official programmes. One example is the first degree science programme in Belgium²⁶. This process has also been described by André Giordan²⁷.

3 Interdisciplinary problems

A number of the approaches, tools and contents derived from the field of science and technology can profitably be applied in other disciplines. Moreover, some transversal subjects make use of science and technology as well as of other disciplines.

3.1 Scientific methods of investigation applicable in other disciplines

A number of methods of relating to reality and knowledge are derived from science and technology. However, they may profitably be used in other disciplines. In the science programme of the Province of Ontario, it is stated²⁸, for example, that science is not only a

²⁶ Internal note by the Ministry of Education of the Province of Quebec, Canada, March 2001.

²⁷ Giordan, André, "Une didactique pour les sciences expérimentales" (A teaching method for experimental sciences), guide Belin de l'enseignement, Belin, France, 1999.

²⁸ Mentioned in an internal note to the Ministry of Education of the Province of Quebec, Canada, March 2001.

compendium of knowledge but also a "way of knowing" (e.g. through exploration, experimentation, observation, measurement, analysis and dissemination of data). These activities require special skills and attitudes (such as precision, discipline, integrity in the application of scientific principles, etc.); technology is also a "way of knowing" and a process of exploration and experimentation. Technological research is based on the application of a "design process", which with the help of concepts and methods consists in determining a requirement or circumscribing a problem and selecting the best solution (e.g. designing a periscope in fourth grade).

Scientific methods, as a thought-forming learning objective, are described in the work edited by William F. McComas²⁹.

3.2 Questions of ethics and citizenship

On the borderline between the fields of education, knowledge, culture, ethics, responsibility, science and society, ethics and citizenship occupy an important place.

They reflect the shift in educational objectives, which have broadened their scope to encompass culture and responsible integration within society.

Where ethics is concerned, it is probably in biology and in medicine that most of the subjects and discussions are to be found, since their development opens up new possibilities, which may in turn impact the individual, the community, the future and the species. This is a field that draws on philosophy, literature, economics and science in order to express beliefs and personal choices, as a matter of conscience. For G. Charpak, "education is a good barrier against barbarism"³⁰, following on directly from the principles of Jean-Jacques Rousseau. In his view, moreover, training for citizenship in part requires "civic" service within a community³¹. Training for citizenship is discussed in some detail in the collective work "Construire ses savoirs, construire sa citoyenneté"³² and in Edgar Morin's "La tête bien faite"³³.

Issues on the borderline between ethics, citizenship and science, such as the question of differences between races and relations between science and race, intellectual independence and the exercise of democracy, are treated in "Problems of Meaning in Science Curriculum"³⁴.

Citizenship covers a broader field, partly related to science and technology. The growing interpenetration between science, technology, economics and society has been creating

²⁹ McComas, William F., ed., "The Nature of Science in Science Education, Rationales and Strategies", Science & Technology Education Library, Kluwer Academic Publishers, Netherlands, 1998.

³⁰ Charpak, Georges, ed., "Enfants, chercheurs et citoyens" (Children, scientists, and citizens), Editions Odile Jacob, France, 1998, p. 11.

³¹ Charpak, Georges, op. cit, p 211.

³² "Construire ses savoirs, construire sa citoyenneté" (Building one's knowledge, building one's citizenship), Pédagogie formation - l'essentiel, Chronique sociale, France, 1996.

³³ Morin, Edgar, "La tête bien faite" (A clear mind), L'histoire immédiate, Seuil, France, 1999.

³⁴ "Problems of Meaning in Science Curriculum", Douglas A. Roberts, Leif Ostman, Editors, Teachers College Press, New York, 1998.

problems with democracy arising from science and technology. These problems include issues such as management of the planet, the environment, energy, water, major research equipment (especially in physics) or public research policy. These topics are situated on the borderline of such areas as science, philosophy, literature, law and knowledge of institutions.

3.3 Access to and practice of Information and Communication Technologies (ICTs)

Where education and training are concerned, ICTs can play three different roles.

Firstly, because they are becoming an indispensable tool of all professional activity, knowledge of ICTs is an end in itself. All young people must have access to them and must acquire the ability to use these tools reasonably independently. This mastery of the ICT tool is an objective, especially in all vocational training courses.

The second role relates to distance teaching. There are more and more forms of teaching where instructors and learners are not in close physical proximity. ICTs can provide access to rare disciplines or to small numbers of instructors in every part of a country, including the most remote. The educational rules of distance teaching have not yet been clearly established. Nevertheless, there is no doubt that considerable developments may be expected, in both initial training and vocational training.

The third role is that of any tool, which is to serve as a means to an end. ICTs, just like any other tools such as books, blackboards or slides, provide the means of achieving some of education's traditional objectives. It is this third role which we would like to look at in a little more detail.

3.3.1 Tools for pursuing traditional educational objectives

Together with other tools, ICTs provide the means of pursuing three major types of traditional educational objectives.

Firstly, they may be used to **search for information**. This type of activity is important and allows the learner a certain independence. It is basically similar to the documentary research referred to above.

The second type of activity is related to **the drafting of summary reports**. After a phase of research, one essential intellectual activity consists in summing up what has been done, that is, collating, ordering and restating the information which has been gathered. This exercise is nowadays carried out on other tools, with which new forms of documents can be produced, for instance multimedia documents using HTML editing software, which is like a word processor incorporating different types of media.

The third facility they offer is the ability to **communicate and work at a distance**. Thanks to these new communication tools, distant students or groups of students can be made to work together, either on-line or off-line, while teachers can direct distant groups of students, which implies a substantial change in teaching methods.

These three types of objectives are not new. They have been around for dozens of years, not to say centuries. The emergence of ICTs, however, has opened up new prospects, allowing coverage of considerable quantities of information and a variety of sources, while producing information in new forms. Furthermore, because they are present in every aspect of everyday life and in professional activity, the ability to use and to master ICTs has become indispensable.

This does not mean to say that other media should be completely abandoned. Real objects, books or newspapers must still be given an important place in teaching. Successful training

depends on a variety of media and while some may be virtual, many must remain real. It is extremely dangerous to devote the bulk of the operating budget of schools to computing at the expense of equipment for practical work, books, outings or the purchase of various objects. Social discrimination is not an effect only of access to ICTs; access to encyclopaedias, newspapers, theatres and museums is at least as important as access to computing as a means of reducing the social divide.

These tools should be seen as catalysts, a new window opening up school contents to society and current events, as well as a new opportunity to reform teaching practice and make it more innovative.

3.3.2 How is the role of the teacher evolving?

Acquiring a mastery of these tools is not easy for teachers. The fact that there are so many in itself produces a strong sense of inertia. Moreover, introducing such tools in the classroom requires changes in teaching practice which are difficult to anticipate and to manage for teachers.

Often the problem is raised that teachers may find themselves faced with young people who may be able to handle ICTs better than they can. This greater ability on the part of youngsters is often undeniable and it is probably unnecessary for the teacher to try to outdo the student. The competition will not be easy and the point to bear in mind is that such skills are not part of the teacher's trade: the special asset a teacher offers, his added value in the system, is not his technical mastery of the tool, but his mastery of its use in education.

Each country, depending on its system (either centralized or federal) has its own approach to facilitating the development of ICTs. France, for example, has emphasized three priorities:

- Supplying schools with equipment;
- Training teachers and backing their initiatives;
- Encouraging multimedia production and publishing.

Another issue which is frequently raised is whether teachers can be replaced by machines. Even removing a single teacher on the grounds of increased use of machines would be extremely risky. No automatic system, research engine or intelligent agent can circumvent human mediation between the learner and the source of information.

One of the main changes has been the new type of relation that is emerging between the different actors.

Traditionally, teaching activity gives rise to an asymmetric relation between the teacher and the learner: the teacher, who masters knowledge and the concepts of information processing, passes on knowledge and at a subsidiary level methodological tools to a learner, who interacts relatively little with the teacher. In addition, interactions between learners are little developed.

In the new type of situation, in which the introduction of ICTs has acted as a catalyst, the teacher no longer has a monopoly of knowledge; information becomes dehumanized and introduces a third actor in the scenario. This triangular relation between three actors, i.e. the teacher, the learner and the information source, is completely different to the previous type of situation. Information circulates more easily and in a more balanced fashion between teacher and learner; the teacher's added value is more fundamentally methodological and interactions between learners become more numerous.

In order to adjust to this change, the following specific abilities of the teacher are indispensable:

- Ability to conceive the development of the learning activity and to individualize progress;
- Ability to give operational expression to doubts and queries;
- Ability to conduct a research method, in order to ensure that the students acquire the necessary methodological tools as well as a critical appreciation of results;
- Ability to restate and to sum up;
- Partial mastery of contents;
- Ability to perform certain types of evaluation.

These abilities are not new, but they will need to be perfected and confirmed as original abilities pertaining to teachers. This will require greater attention to training and to assessment.

There are other obstacles. For example, the investment needed to equip schools is considerable. Moreover, as is always the case when new know-how is being acquired, it is not easy to achieve the right balance between initiatives by individual teachers and general guidelines, which ensure compatibility between such initiatives and which enhance and facilitate the exchange of innovations³⁵. A few aspects of the general educational framework needed to manage ICTs in the classroom are presented by J. Tardif³⁶.

Lastly, in conclusion, the introduction of ICTs in the classroom is bound to have an impact on timetables, the size of sections and even on school architecture. This is a major upheaval in the making.

³⁵ A number of innovations are suggested in the work: Baron, Georges-Louis; Bruillard Eric; Lévy, Jean-François, "Les technologies dans la classe - de l'innovation à l'intégration" (Technology in the classroom - from innovation to integration), EPI-INRP, France, 2000.

³⁶ Tardif, Jacques, "Intégrer les nouvelles technologies de l'information - Quel cadre pédagogique?" (What is the best educational framework for integrating the new information technologies?), collection Pratiques & enjeux pédagogiques, ESF éditeur, France, 1998.

The World Conference on Science, organized jointly in Budapest in 1999 by UNESCO and the International Council for Science (ICS), adopted a “Declaration on science and the use of scientific knowledge”, in which it is stated:

- that “access to scientific knowledge for peaceful purposes from a very early age is part of the right to education belonging to all men and women, and that science education is essential for human development, for creating endogenous scientific capacity and for having active and informed citizens”;
- that “the essence of scientific thinking is the ability to examine problems from different perspectives and seek explanations of natural and social phenomena, constantly submitted to critical analysis. Science thus relies on critical and free thinking, which is essential in a democratic world.”
- that “today, more than ever, science and its applications are indispensable for development. All levels of government and the private sector should provide enhanced support for building up an adequate and evenly distributed scientific and technological capacity through appropriate education and research programs as an indispensable foundation for economic, social, cultural and environmentally sound development. This is particularly urgent for developing countries.”
- that “Science education, in the broad sense, without discrimination and encompassing all levels and modalities, is a fundamental prerequisite for democracy and for ensuring sustainable development. In recent years, worldwide measures have been undertaken to promote basic education for all. It is essential that the fundamental role played by women in the application of scientific development to food production and health care be fully recognized, and efforts made to strengthen their understanding of scientific advances in these areas. It is on this platform that science education, communication and popularization need to be built. Special attention still needs to be given to marginalized groups. It is more than ever necessary to develop and expand science literacy in all cultures and all sectors of society as well as reasoning ability and skills and an appreciation of ethical values, so as to improve public participation in decision-making related to the application of new knowledge.”
- that “the social responsibility of scientists requires that they maintain high standards of scientific integrity and quality control, share their knowledge, communicate with the public and educate the younger generation. Political authorities should respect such action by scientists. Science curricula should include science ethics, as well as training in the history and philosophy of science and its cultural impact.”

The “Agenda for science” adopted by the World Conference devoted several paragraphs to science teaching, emphasizing the following points:

“Governments should accord the highest priority to improving science education at all levels, with particular attention to the elimination of the effects of gender bias and bias against disadvantaged groups, raising public awareness of science and fostering its popularization. Steps need to be taken to promote the professional development of teachers and educators in the face of change and special efforts should be made to address the lack of appropriately trained science teachers and educators, in particular in developing countries” (...);

“New curricula, teaching methodologies and resources taking into account gender and cultural diversity should be developed by national education systems in response to the changing educational needs of societies. Research in science and technology education needs to be furthered nationally and internationally through the establishment and networking of specialized centers around the world, with the cooperation of UNESCO and other relevant international organizations.”

“National authorities and funding institutions should promote the role of science museums and centers as important elements in public education in science. Recognizing the resource constraints of developing countries, distance education should be used extensively to complement existing formal and non-formal education.”

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