SCIENCE AND TECHNOLOGY IN THE PUBLIC EYE

FOREWORD

While the importance of science and technology for society has long been recognised, they have taken on ever increasing importance in the present century, particularly in the last 25 years. As a result, governments and other concerned bodies have heightened their efforts to inform the public about the nature and role of science and technology, so as to make citizens both better informed and better able to adapt to the many changes that science and technology have brought, and will continue to bring, to their lives.

Despite these efforts, many citizens remain ill-informed about scientific advances, about how science pushes back the frontiers of knowledge, about precisely how technology affects their lives. As a result, most members of the public are unable to form substantiated judgements about matters involving science and technology, particularly in the area of policy. It is essential that today's leaders find ways to improve public understanding of science and technology. In particular, an ongoing concern of a number of OECD Member countries is the decline in young people's interest in scientific studies and in careers in science and technology.

This brochure summarises the contributions to and the conclusions of an OECD symposium on these issues, held in Tokyo in November 1996, at the invitation of the Japanese Government. It presents comparative data in public understanding of S&T in 14 OECD countries. It indicates efforts that have been made to improve the teaching of science and technology to young people. It describes noteworthy efforts to make information on science and technology more readily available to the public, in more interesting form. Finally, it proposes measures that the various actors might usefully take to improve public understanding of science and technology. This conference and publication have been undertaken under the auspices of the Group on the Science System of the OECD Committee for Scientific and Technological Policy. The brochure is derestricted on the responsibility of the Secretary-General of the OECD.

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THE GENERAL PICTURE

In today's world, science and technology (S&T) have taken on ever greater importance in daily life, a trend that will continue as we enter the 21st century. They have brought untold advances in medicine, communication, and transportation, making our everyday world vastly different from that of earlier generations. While they have brought immense benefits, they have also given rise to questions about how they affect our lives, questions which most of the population, even in advanced countries, lacks the scientific background to address. This leads to a somewhat paradoxical situation: the public generally recognises the value of science and technology but, at the same time, does not adequately understand the issues related to or arising from them.

In particular, there are insufficient, and not always effective, opportunities for leaders, social groups, and the general public to participate together in making strategic S&T choices and to take advantage of scientific expertise in order to understand certain crucial issues with broad-ranging social consequences: the location of nuclear power plants and the disposal of nuclear wastes, blood contaminated with the HIV virus, BSE or "mad cow" disease, the planting or use of transgenic plants as food and, more generally, recombinant DNA field tests, genetic testing, cloning, the uses of information technologies, etc.

With some exceptions, such as research on certain diseases, the general public's support for science and technology is often lukewarm. Yet today, government efforts on behalf of research and development (R&D) are coming under scrutiny or being reduced owing to the **serious budgetary restrictions** that presently affect almost all industrialised countries. Moreover, in many countries, **young people show less interest** in studies and careers in the so-called "hard" sciences and in technology than in the past. If this trend continues, it will have serious consequences for maintaining sufficient numbers of researchers in the coming decade as large bodies of researchers retire. Finally, the general population's **technical culture appears very inadequate**. This is particularly serious among young people, those who will need to work in economies that will be strongly – and increasingly – affected by rapid technical change.

WHAT THE STATISTICS TELL US

Today, there are many competing demands for any individual's attention, and about half the population in most industrialised countries devotes little time to issues of public policy. However, survey evidence from 14 countries (Miller, 1996) indicates that, with the notable exception of Japan, ***a majority of citizens have a high level of interest in scientific and technical areas that affect their daily lives directly***, such as environmental pollution or medical discoveries, and that a slightly lower proportion is interested in new scientific discoveries or new technologies and inventions (Table 1). Citizens of the industrial world generally seem to recognise the importance of science and technology both for their personal lives and as a matter of public policy. However, they are often less aware of the role it plays in social and economic development.

Table 1. Comparative indices of interest in issues

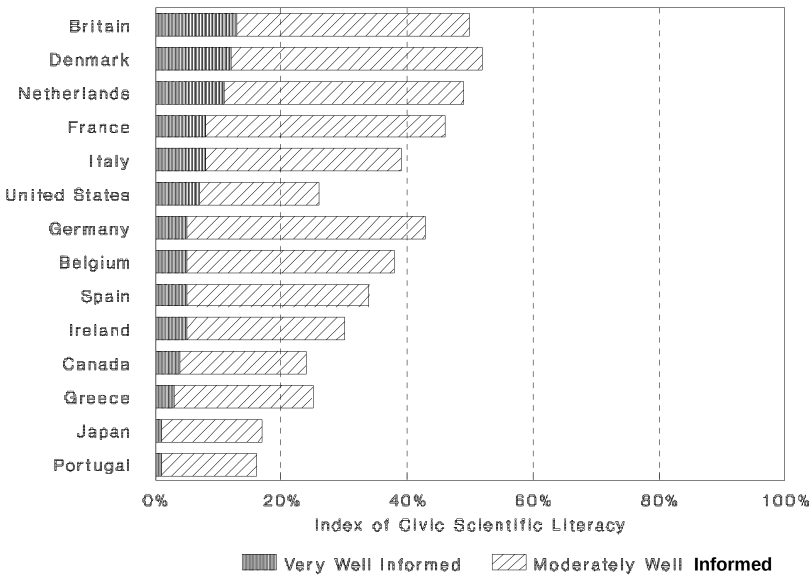
	New scientific discoveries	New inventions & technologies	New medical discoveries	Environmental pollution	Number of persons interviewed
Canada	63	59	77	74	2 000
Japan	31	35	52	59	1 450
United States	67	66	83	74	2 006
Europe					
Belgium	53	52	60	67	1 000
United Kingdom	64	62	72	71	1 000
Denmark	62	59	61	79	1 000
France	68	65	76	77	1 000
Germany	51	50	60	74	2 000
Greece	67	66	75	86	1 000
Ireland	49	51	58	60	1 000
Italy	65	61	67	80	1 000
Netherlands	63	65	75	80	1 000
Portugal	46	44	54	62	1 000
Spain	58	56	63	71	1 000

Note: Cell entries are the mean national score on the "Index of issue interest". For each issue, 100 reflects "very interested" in an issue, 50 represents "moderately interested" in an issue, and zero reflects little or no interest in an issue.

Source: Miller, 1996.

The level of civic scientific literacy may be defined as the level of scientific understanding necessary to examine competing arguments in a public policy framework. It implies an understanding of basic scientific terms and concepts and of scientific methods. An analysis of survey results aimed at determining civic scientific literacy indicates that only ***slightly over 10 per cent of the population of 14 industrialised countries has a good understanding both of scientific concepts and methods*** and that only 20 to 30 per cent more showed adequate understanding of either one or the other (Figure 1). It is therefore likely that not more than two out of ten citizens, at most, would be able to follow and participate in a controversy involving a scientific or technical issue.

Figure 1. Civic scientific literacy in 14 nations



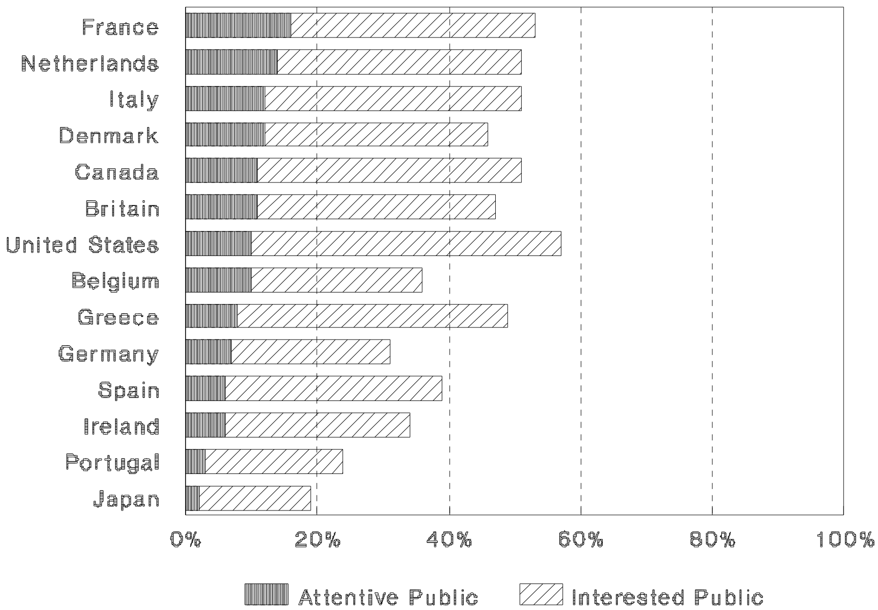
Source: Miller, 1996.

Further analysis of survey data reveals that of three independent variables examined – age, gender, and formal education – ***formal education is the strongest predictor of civic scientific literacy*** (although certain variations suggest the need for further examination of students' exposure to courses in science and mathematics). Women are consistently less likely to be scientifically literate than men, even when age and educational attainment are held constant, confirmation that, as other studies have noted, women have traditionally taken fewer science and mathematics courses and have been less likely to choose careers in science and engineering. Generally speaking, women appear to show more interest in medical discoveries and men in technological innovations. In the United States, the only country studied where educational attainment does not differ significantly by age, younger people were more likely to qualify as scientifically literate than older people.

While citizens must have a high level of interest in science and technology and be scientifically literate if they are to participate in discussions of S&T policy, this is not, in itself, enough. They must also constitute an "attentive" public, one which follows the relevant issues on a regular, even daily, basis. There is certainly an *attentive public* for every policy issue, but it is a rare individual who is able to follow closely more than two or three issues.

Even among citizens interested in science and technology issues, those who follow them closely account for a small proportion of the population, ranging from 16 per cent in France to 2 per cent in Japan (Figure 2). Under certain circumstances, some interested citizens may temporarily become attentive citizens. This is most likely to occur when the issue is a local one (for example, in the case of a dispute over the location of nuclear or chemical waste) or a personal one (such as genetically-based disease).

Figure 2. Attentiveness to science and technology in 14 countries



Source: Miller, 1996.

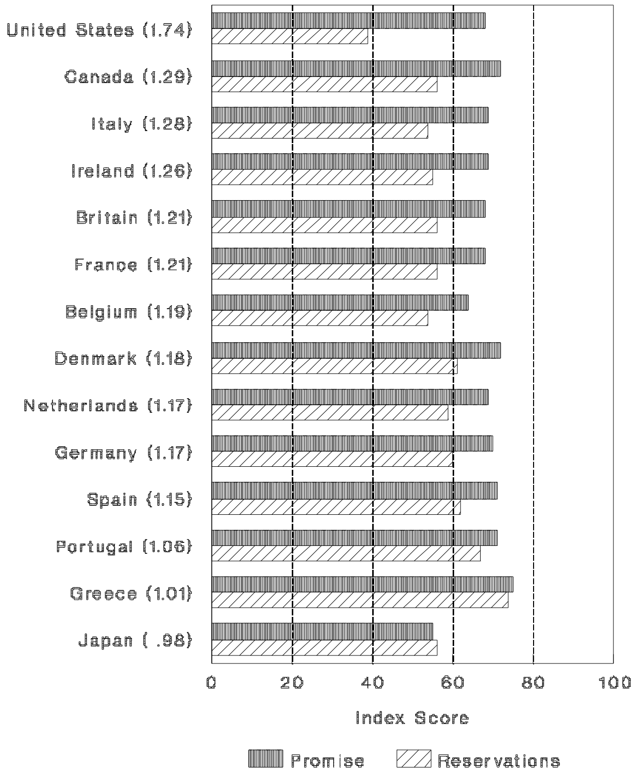
The public's level of attentiveness may be attributable in part to the visibility of the related issues and to controversies, as well as to its perception of its ability to influence policy decisions. Moreover, while the input of attentive citizens to policy decisions is to some extent a function of the decision-making processes of their countries, it is most likely to be sought when there is a divergence of views among policy leaders, decision makers, and, on occasion, the science and technology community itself.

Concern with policy issues appears to be highest among adults aged 30-39 in Canada, Japan and the United States, while a younger group, 18-29 years of age, is the most attentive in Europe. This group is moderately less attentive (by 3 per cent) in both Canada and the United States. Among Japanese youth, as among their elders, only 2 per cent are attentive to science policy issues.

Attitude towards science and technology is another relevant dimension of public understanding. When people obtain information of a scientific or technical sort, they generally tend to have either a favourable or an unfavourable bias towards that information. That is, they are likely to emphasize either the potentially positive or the potentially negative aspects of what they learn. Survey results show that the public's attitude towards S&T is more positive in the United States than in European Union countries in general, and considerably more so than in Japan. However, they also indicate that most individuals possess both positive and negative attitudes to a greater or lesser degree. People generally react positively to statements suggesting that science and technology have improved the quality of life and are likely to continue to do so, but have reservations about the speed of change in modern life or about the potential conflicts between scientific advances and values or beliefs. Since most adults have relatively little direct experience with S&T issues, it is likely that many people have relatively weak positive or negative attitudes.

On the basis of an analysis of survey data, Figure 3 indicates the relative strength of positive and negative attitudes towards science and technology in 14 countries and the ratio between them. It is important to recall that the two coexist in most individuals: a given person may respond favourably to news about medical testing but unfavourably to news about the testing of a nuclear weapon.

Figure 3. General attitudes towards science and technology in 14 countries

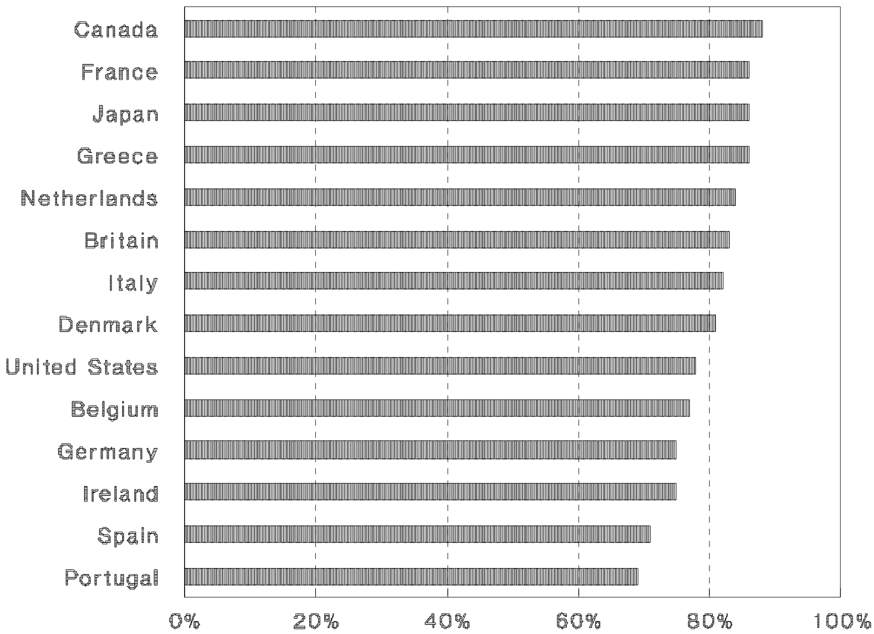


Source: Miller, 1996.

When asked whether government should provide support for basic research, an overwhelming majority reply in the affirmative (Figure 4). More detailed analysis shows, however, that what underpins this view – in terms of interest, scientific literacy, attentiveness, and attitude, as well as background factors such as age, gender and educational attainment – varies from countries to country. Thus, in France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain and the United Kingdom, the principal reason for support appears to be a belief in the promise of science; reservations about the negative impacts of S&T are unrelated to attitudes towards spending for basic science. In Belgium, Japan and the United States, it appears to involve attentiveness and both positive and negative attitudes, although Japan is somewhat unusual, given its relatively high level of reservations. In Denmark, the basis appears to be a combination of attentiveness to S&T policy and a rejection of reservations about science and technology. Finally, in Canada, which showed the highest level of support for spending on basic science, support for basic research appears to be linked to educational attainment and civic scientific literacy.

Figure 4. Approval for government funding of basic scientific research in 14 countries

Percentage

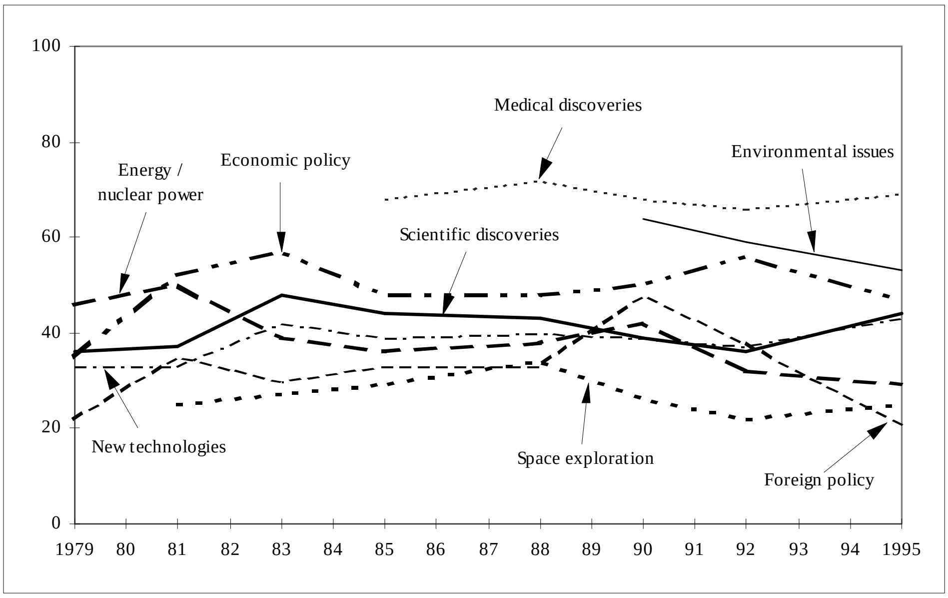


Source: Miller, 1996.

It has also been shown that public support for basic research is clearest when the research is considered useful and socially relevant. When it is considered non-useful or morally contentious, the generally strong correlation between scientific literacy and/or attentiveness and support for research disappears or even, in the latter case, becomes negative.

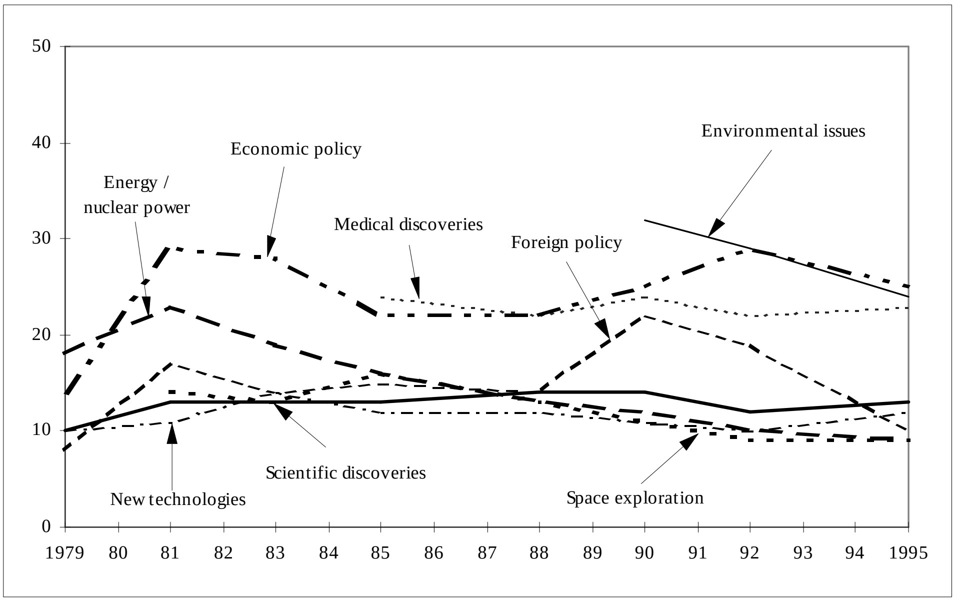
Governments and interested organisations have long taken initiatives designed to interest the public in science and technology. Over the past 15 years, with the arrival of new technologies, their efforts have multiplied and taken a number of forms: greater emphasis on science and technology in education, the development of science centres and museums, the creation of national science and technology days or weeks, greater numbers of radio and television programmes. ***Levels of interest in various aspects of science and technology have, as the example of the United States shows, tended to remain quite stable over the years*** (Figures 5 and 6)***. As a result, greater efforts to boost public interest will be needed in order to meet the needs of the 21st century.***

Figure 5. Public interest in selected policy issues in the United States
Percentage reporting a high level of interest



Source: National Science Foundation, 1996.

Figure 6. Public understanding of selected policy issues in the United States
Percentage reporting to be very well informed



Source: National Science Foundation, 1996.

YOUNG PEOPLE AND SCIENCE AND TECHNOLOGY

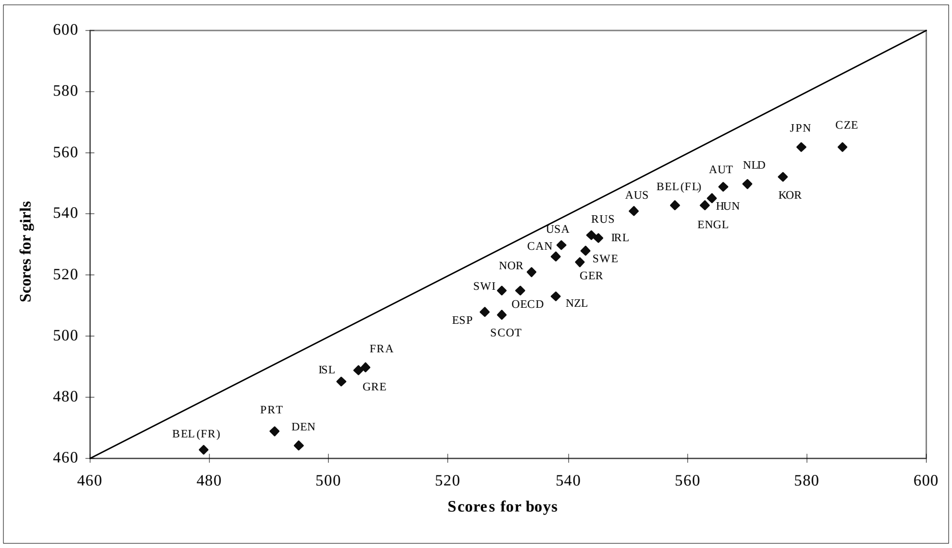
Issues involving science and technology policy are certain to take on greater importance in the future. It is therefore particularly important to understand how much interest today's schoolchildren and students take in scientific and technical subjects and to what extent they consider undertaking scientific or technical careers. It is also generally recognised that efforts to interest young people in these areas must begin early and go beyond the classroom.

In general, ***the attitudes of young people in most countries are not very different from those of their elders***. Young people have a broadly positive attitude to science and technology in most OECD countries. Japan is a notable exception, according to a study which shows that interest fell consistently among those aged 20 to 29 between 1981 and 1995 (from 55 per cent to around 45 per cent), whereas interest among those aged 50 to 59 rose consistently (from around 50 per cent to around 65 per cent). Not surprisingly, studies have shown that students' attitudes to science are positively, and generally significantly, correlated with their science achievement.

On the other hand, young people's understanding of science and technology appears better than that of their elders, largely owing to the rise in the level of educational attainment over time. ***Schooling is the primary source of understanding of and interest in science and, increasingly, technology.*** More specifically, an early sense of mastery of scientific or technical topics, as well as popular views about science and technology, affect how young people react to their studies in these areas. A study by the *International Association for the Evaluation of Educational Achievement* revealed that between 1970/71 and 1983/84 10-year-olds and 14-year-olds showed gains of two-thirds and one-third of a school year of science learning, respectively. Moreover, as for adults, science and technology must vie with other areas for their attention.

The gender difference in understanding of science and technology, noted in surveys of adults, is already evident at age 13, although it is greater in some countries than in others. In mathematics, the gender gap is generally moderate. In science, instead, it is wide in all OECD countries (Figure 7). The differences are statistically significant everywhere except in Australia, Belgium's Flemish community, Ireland, and the United States. Countries with relatively large gender differences in science also tend to have large gender differences in mathematics. The Czech Republic, Denmark and Korea show relatively large gender differences in both science and maths, with Norway and the United States (two countries known to have equity goals) showing relatively small differences. However, while both Japan and Korea have large gender differences in maths, the average achievement of girls in both countries is better than the average achievement of both boys and girls in all other OECD countries (OECD, 1996*a*).

Figure 7. Mean science achievement scores by gender in eighth grade (1995)



Source: OECD, 1996*b*.

Recent evidence suggests that ***young people who choose to study scientific or technical subjects and/or eventually choose a career in science and technology do so not on the basis of a single determining factor, but as the result of a series of events and influences***. A study of senior secondary school students in Australia indicates that earlier results at school significantly influence enrolments in particular subjects. Thus, those who were high achievers (either in literacy or numeracy) showed considerably higher enrolments in courses in the physical sciences and mathematics, while the reverse was true for technical ones. In addition, they were twice as likely to be male as female and were more likely to come from a higher socio-economic background. More generally, ***students' choices of subjects reflected their interest and enjoyment, as well as relevance to future work or study***. The reasons given for studying mathematics and the physical sciences were often their relevance to future study, and for computing, its relevance to work.

Trend in enrolments

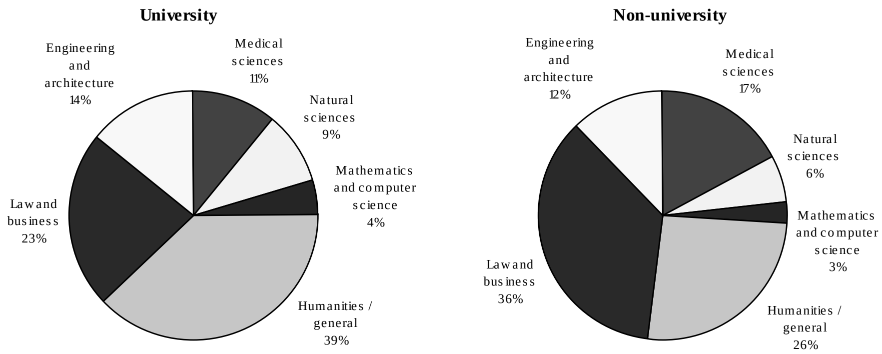
According to an OECD study (OECD, 1996*a*), 53 per cent of upper secondary students in OECD countries in 1994 were enrolled in vocational and technical programmes and 47 per cent in general programmes. For women, the figures were 49.4 and 50.6 per cent, respectively. Japan, Ireland, Mexico and Portugal had over 70 per cent in general programmes, while more than 70 per cent were in vocational and technical programmes in the Czech Republic, Italy and Hungary as well as in Austria, Germany, the Netherlands and Switzerland, countries with dual-system apprenticeship programmes. The study also indicates that ***participation in vocational programmes at upper secondary level has grown noticeably over the last decade***.

OECD area graduates at the tertiary level (university and non-university post-secondary education) for 1994 are shown in Figure 8. However, certain countries diverge notably from the norm. More than 40 per cent of all university-level graduates in the Czech Republic, Finland and Germany are in the sciences (natural sciences, mathematics, computer science, engineering and architecture). In terms of gender, while overall university graduation rates do not differ significantly between men and women, ***women account for less than 25 per cent of scientific graduates***, except in Korea and Turkey, where they account for 26 per cent. On the other hand, more than 25 per cent of all male graduates are in science-related fields, and the share reaches 50 per cent in the Czech Republic, Finland and Germany. Also, while less than 10 per cent of women graduate from engineering or architecture programmes, except in the Czech Republic and Turkey, more than 20 per cent of male graduates are in these fields in 16 OECD countries. However, there are more women than men graduating in the medical sciences in all OECD countries except Greece and Italy. Gender differences tend to be less marked at the non-university tertiary level, where programmes are often considerably shorter than at the university level (OECD, 1996*a*).

Between 1975 and 1992, higher education in science and engineering expanded rapidly in several regions, primarily because of the large overall increase in university-level studies. In 1992, more than 1 million students graduated with a university degree in natural sciences or engineering in a range of countries in Asia, Europe and North America [National Science Foundation (NSF), 1996]. The balance was slightly towards engineering in Europe and six

Asian countries (China, Chinese Taipei, India, Japan, Korea and Singapore) and towards the natural sciences in North America. Over the period, degrees awarded grew by 9 per cent a year in Korea and Singapore, and China now produces the largest number of engineering degrees in Asia, with a growth rate of 6 per cent a year. In Europe, science and engineering courses have led a dramatic expansion of higher education since 1975. This has been aided, in several countries, by the establishment of a non-university tertiary sector. Between 1975 and 1991, first-level university degrees in science and engineering doubled in western Europe, and there was a 4.5 per cent increase in the natural sciences and a 5 per cent in engineering degrees, despite a decrease in the size of the relevant age cohort (20-24 years) in western Europe, the United States and, in Asia, in Chinese Taipei, Japan, Korea and Singapore.

Figure 8. University and non-university tertiary qualifications by field of study in OECD countries, 1994



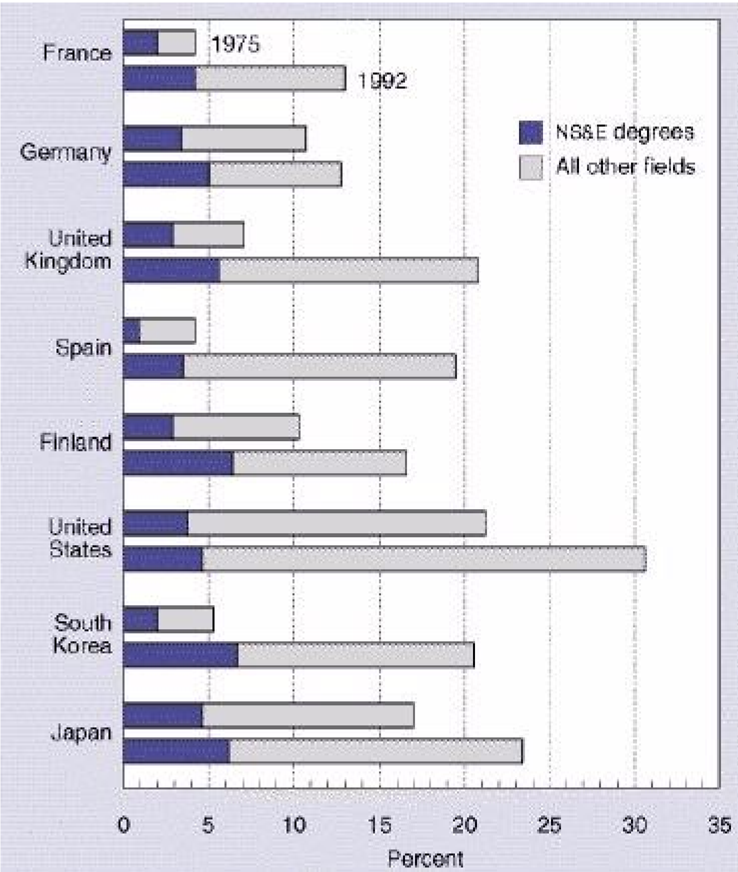
Source: OECD, 1996*b*.

However***, as a share of total degrees, the proportion of science and technology degrees has dropped*** (*see* Figure 9). In Japan, undergraduate applications to study science and technology have remained quite stable; following a drop in the early 1990s, they have since recovered. However, while applicants for master's degrees in science and technology have kept pace with the overall increase in master's degree applicants, applicants for PhD programmes have increased more slowly that the overall numbers of applicants and even showed a slight decrease in 1996.

Norway notes that while enrolments in engineering and science faculties increased over the decade 1983-93, their relative share of the student population has declined; in some areas, college-level engineering schools have been unable to attract enough qualified students to fill the places available.

Sweden also reports difficulties in recruiting students to training programmes in science and engineering, except in biology (environment, health), and Australia has had to lower threshold entrance scores in order to fill university quotas for some courses. The United States, for its part, has seen a significant drop in enrolments in optional science courses at the secondary level, and in some universities, physics courses no longer attract enough students and are cancelled. Overall, there appears to be some movement away from the physical sciences and engineering, while the biological and social sciences remain steady.

Figure 9. Ratio of first university degrees and NSE&E degrees to the 24-year old population, by country: 1975 and 1992



Source: NSF, 1996.

Careers in science and technology

The figures given above generally suggest a robust and growing S&T sector in OECD countries, although more detailed evidence indicates some internal shifts and some indications of declining interest and areas of concern. Moreover, certain segments of the professional S&T community perceive a drift away from science and technology among young people, and this is a definite source of concern.

The number of students studying science and engineering tends to decrease as the cohort ages. In the United States, the number of women drops significantly between the ages of 17 and 19 (National Research Council, 1995). As wider socio-economic circumstances play a role in career choices, it has been asked whether the trend away from science and technology may not be due to a loss of prestige associated with such areas.

In terms of the potential supply of high-level skills and knowledge in science-related fields, OECD countries vary markedly. In 1994, there were more than 1 200 university-level graduates in science-related fields per 100 000 people in the labour force aged 25 to 34 in Australia, Ireland, Japan and Korea, but there were fewer than 500 per 100 000 in eight OECD countries. On average, there were 745 university-level graduates per 100 000 and 376 non-university tertiary graduates.

Science and technology graduates have three main fields of employment within their discipline:

◊ *research in "big" or "small" science in universities, research institutes (private and public), government and industry;*

◊ *teaching combined with research at university level, or teaching at school level, for community groups or as education officers in museums and the like;*

◊ *work in commerce and industry.*

However, while available data are limited, it is clear that ***a notable proportion of degree recipients in science and technology choose to work in others fields***. In itself, this is not necessarily a bad thing: they bring to various economic sectors scientific knowledge and ways of thinking that can be of benefit to these sectors. The problem to be addressed is two-fold. First is the need to ensure that the S&T sectors obtain the necessary mass of high-level employees necessary for their adequate development. Second is the fact that ***significant numbers of youth leave the educational system without the basic S&T culture that they need to find jobs in an increasingly technological economy and participate as informed citizens in issues involving science and technology***.

EDUCATING FOR SCIENCE AND TECHNOLOGY

If public interest in science and technology and civic scientific literacy are to be improved, the main effort must be made in the area of education. ***Comparative surveys clearly indicate that interest in science, technology and mathematics essentially develops at the primary and secondary levels of education.*** Later learning is important, but it is very difficult to fill the gaps left in early years. The problem is how to teach these subjects so as to awaken the interest of young students. Young people often complain that the subjects are boring, irrelevant to "real life" and difficult (*see* Box A).

Box A. Why competent students drop out of mathematics and science

A decade-long Swedish study (1982-92) followed students from grade 3. In the course of the study, scores on intelligence and achievement tests, replies to questionnaires on attitudes to school and spare-time interests, and information on social background were compiled.

In grade 6, a reasoning test was given, which has high correlation with school marks and standardized achievement tests in mathematics; it was considered a measure of aptitude for scientific and technical studies. The number of students scoring above the mean was compared to the number who later completed technical or science programmes. While 17 per cent of students had completed such studies, an almost equal share would have been able to do so as well. The first group was dominated by male students from higher socio-economic groups; this was not the case for the second.

An important reason for not entering technical or science programmes was declining interest in mathematics in grades 7 through 9. Many students had difficulty in understanding teachers' instructions and felt they did not receive the support they needed. Many gifted students who had enjoyed mathematics in earlier grades either shifted to easier courses or received rather low marks. They found the subject too abstract and boring.

It is true that there has long been criticism of the teaching of science, technology and mathematics throughout educational systems. Japan, for example, has recognised that its educational system has tended to place too much emphasis on information and exam-passing techniques. Lessons are dense and students tend to memorise passively the patterns needed to answer test questions. It is thought that students are unable to discover problems and determine how to solve them and unwilling to make the effort to do so, and this may well be a self-fulfilling prophecy. Current innovations, in Japan as elsewhere, are directed towards making courses more relevant to the larger numbers of students now completing secondary school and entering tertiary education (*see* Box B).

Box B. Benchmarks for science literacy

"If we want students to learn science, mathematics and technology well, we must radically reduce the sheer amount of material now being covered. The overstuffed curriculum places a premium on the ability to commit terms, algorithms, and generalisations to short-term memory and impedes the acquisition of understanding…. The common core of learning in science, mathematics and technology should centre on science literacy, not on an understanding of each of the separate disciplines. Moreover, the core studies should include connections among science, mathematics, and technology and between those areas and the arts and humanities and the vocational subjects."

Source: American Association for the Advancement of Science, 1993.

At school level, maths and language are core subjects in most systems from the earliest years, and competence in language and maths are widely perceived as central to primary education, although teaching methods differ widely from country to country. However, ***neither science nor technology has achieved a recognised and central place in primary schools.*** While both are widely taught (for example, through nature studies), there are marked differences in policy emphasis, as well as differences related to grade level and individual teachers' interests and commitment.

With the recent move in many countries towards adopting a core curriculum and national standards, science teaching has taken on greater emphasis at the primary level, although the same cannot be said for technology. If these trends continue and are acted on, children now in primary schools can be expected to have a more systematic and significant introduction to these fields during their early and formative years. ***Efforts are also needed to increase the share of young women studying science and technology*** throughout their educational careers, a problem that the Netherlands, for example, has sought to address (*see* Box C).

At the secondary level, students generally have some experience of studying science, either through a general introductory course or in specific disciplines. Where core curricula exist, science is generally included. Again, technology is a different matter. It has its origins in the courses in crafts and trades in dedicated institutions or streams. In the past, students planning higher education studies in engineering followed a more academic path of courses in mathematics and science. However, ***as more students stay longer at school, as too narrow a range of skills has become an obstacle in the changing employment market, and as the part technology should play in general education is reconsidered, some emphasis has been placed on courses addressing technological design and its role in society.***

Box C. Encouraging young women to study science and technology in the Netherlands

In recognition of the fact that most young women do not choose to study scientific and technological subjects in their general education, and thus do not choose technical careers (women account for 6 per cent of the labour force in construction, 7 per cent in the electrical field, and 2 per cent in metals industries), the Netherlands has made both formal and informal educational efforts. Since 1993, all secondary students study technology (or engineering) as part of the core curriculum, and technology has also been integrated into primary education. Technika-10 is a club that brings together girls aged 8 to 14 to learn about and share interests in technical areas. The Netherlands also gives support to industry for sharing experiences in finding and hiring women for technical jobs and finances mass media campaigns aimed at women. It is worth noting as well that the number of female first-year university students enrolled in science and technical subjects rose from 4 per cent to 15 per cent from 1970 to 1990, and the share of graduates grew from 1 per cent to 10 per cent.

This reorientation creates some interface problems for the tertiary level. If secondary level science courses are restructured to meet the needs of the majority, courses will be more broadly based. While some students who plan to enter science and engineering courses at the tertiary level welcome this broader orientation, others object and continue to demand a more focused curriculum. The question then is whether universities will accommodate these changes by facilitating the entry of a less specifically trained student body and ensuring that bridging courses are available where needed.

At present, entry into high-level study of science and technology is often limited by required pre-requisites. Sweden has explored two ways of increasing flexibility in this area. First, students lacking secondary-level competence in science subjects can take a supplementary year of mathematics and science. Also, people who have completed higher studies in a non-science subject and have worked for five years may join a science or engineering programme. In Australia, a bridging course for entering first-year engineering designed for potential students who lack the standard pre-requisites has been effective in increasing the share of women enrolling in engineering, and these students tend to be retained and perform well.

Finally, tertiary-level study was viewed in the past as the end of an education that prepared for adult life and as the direct continuation of secondary-school programmes, but this traditional view is being challenged by two trends: one is increased enrolments of mature students; the other is the introduction of the concept of lifelong learning. Both affect the structure and orientation of programmes of study.

Motivating teachers, motivating students

Given the recognised importance of early education in science and technology, one focus of attention must be teachers at the primary and secondary level. As noted above, students often find the teaching of mathematics, science and technology uninteresting and irrelevant to their lives. ***For their part, many teachers at the primary level feel poorly equipped to teach these subjects, owing to a lack of initial training.*** For example, earlier UK surveys of primary-school teachers showed that they were uneasy when faced with teaching science and technology. However, when these subjects were incorporated into the national curriculum and teachers received considerable in-service work and resource development, they rapidly came to view science teaching in a much more favourable light.

On another front, ***there is likely to be a shortfall of teachers at the secondary level*** in coming years as the current body of teachers retires, a problem for which governments will need to find solutions. In most OECD countries today, there are few employment openings as well structural problems for career advancement in teaching, owing to a combination of the ageing of teachers recruited during the 1960s, when schooling expanded rapidly, and a reduction in new appointments during the late 1970s and 1980s, when school-age cohorts were shrinking. As a result, a rather critical replacement problem is to be expected in the next two decades. Already, the Graduate Teacher Training Registry in the United Kingdom noted that at the end of August 1996, applications for teacher training in secondary-level science and maths courses had dropped from the previous year: down 15 per cent in mathematics, 40 per cent in geology, 26 per cent in physics, 10 per cent in chemistry, and 8 per cent in biology. On the other hand, applications for training in physical education and computing had risen by 135 per cent.

If the teaching of mathematics, science, and technology are to change, attitudes and pedagogical methods will have to be seriously altered. Students need to find a source of motivation, teachers need to become more involved, knowledge needs to be developed from a basis in daily life and in a more concrete, "hands-on" manner. Efforts need to be made to train teachers currently in service who lack a sufficient background in these subjects.

Innovative efforts in the teaching of science and technology have in fact been very successful, as in-depth case studies conducted in 13 OECD Member countries have shown (OECD, 1996*a*). These case studies present a variety of new approaches and identify factors which influence student attitudes to mathematics, science and technology and thus affect public understanding of these areas in adult life. The results suggest that ***if more students are to be attracted to these subjects during their school years, they must become more autonomous learners, the relationships between teacher and learner must change, and the educational system must be adapted to meet these new requirements***.

The studies made clear the need to view students as responsible individuals. ***Subjects should be offered in ways that promote personal interest and engagement***. Often, this implies an integrated approach that takes into account the concerns and lifestyles of today's young people and places the subjects in a context of environmental and social awareness. Emphasis on practical and experiential learning blurs the borderlines between traditional subject areas (physics, chemistry, biology), which students do not generally find relevant to their personal experience. When students lack interest in such subjects, it is important to question the nature and form of the curriculum.

Teachers play a crucial role, not only in the classroom but also in the planning and development of innovative curricula. They should be comfortable with incorporating electronic technology to extend their pedagogical tools, but not constrained by it. For teachers, innovation involves collaboration with peers and with university researchers and policy makers. It also implies enhanced professionalism. Fully equipping teachers for new and more demanding roles requires, among other things, continuing in-service education.

In Australia, for example, the Science Teachers Association is particularly active in promoting science awareness both to science teachers and to school students. It disseminates information about science teaching and major science issues, produces science teaching kits, and organises school science competitions. There are similar programmes for engineering and chemistry. Universities and professional organisations also play an important role for upper secondary school students, notably by organising programmes in which researchers visit schools and community groups to discuss their work.

As the needs of students and teachers become clear, the educational system must respond effectively. Even in an unfavourable environment, young people's interest in and knowledge of science and technology can be raised (*see* Box D).

Box D. Teaching science and technology to Chicago's disadvantaged youth

Chicago has had an extremely poor record in educational achievement. Among its student population, 88 per cent are members of minority groups, 60 per cent live below the poverty line, and the drop-out rate is 40 per cent.

An innovative programme in science and mathematics, led by Nobel Prize winner Leon Lederman, was introduced for pupils in the first eight years of schooling, and 17 000 teachers were trained, using recent findings in cognitive science. Teachers introduced new forms of teaching ("hands on", "contributive thinking", etc.). Classrooms were reorganised to encourage pupils' creativity. Scientists visited the classrooms, and these visits were extremely important to the success of the programme and to supporting teachers' efforts. Because school administrations showed quite strong resistance to the innovations, a sign of their inherent reluctance to change, scientists' support was particularly important.

Because of the programme, pupils have obtained much better results in mathematics and science. Chicago students now stand above the US average in tests of science and mathematics. It is clear that a well-designed approach can result in significant progress. However, the programme has been expensive, and federal and state authorities are considering a reduction in support.

Source: L. Lederman, personal communication.

Recognising the new demands presented by a changing world, Japan's Central Council for Education has developed a new educational philosophy, "The Ability to Live", which emphasizes discovering and solving problems and learning, thinking and judging as individuals. It also emphazises self-discipline, consideration, co-operation with others and appreciation of nature. This philosophy applies to science education as to other areas. In order to cultivate the spirit of creative inquiry, it is considered important to stress active inquiry in educational activities. For scientific subjects, there are a number of specific targets:

◊ *Science classes are to develop student creativeness through appropriately planned use of well-organised science labs.*

◊ *The competence of science teachers is to be improved so that they have a thorough understanding of their subject.*

◊ *Students are to be given more opportunities to come in contact with nature, as well as with scientists and technicians, both in school and in extracurricular activities.*

◊ *Elements of science are to be included in social studies and in technical and homemaking courses.*

◊ *Students are to learn not only to use computers but to understand how they work.*

◊ *Entrance examinations for senior high school and university are to be altered so that they evaluate the ability to think scientifically, to observe and to experiment.*

Japan is also concerned to reorient its university-level studies. There have been nation-wide discussions and something of a national consensus that Japan should open up new economic frontiers by developing new high-technology industries. However, developing new industries requires creativity and originality, areas which have not been the focus of the Japanese educational system. The Ministry of Education, which is responsible for promoting S&T in Japan, has proposed a series of reforms to this end (*see* Box E).

Many countries also have ***programmes specifically designed to foster interest in science and technology among young people, by developing students' interests outside the classroom***. Under CSIRO, for example, Australia's Double Helix Club has 24 000 members in 68 regional chapters and 380 school groups. It produces a magazine regularly and organises annual national science projects. Through its science centres, CSIRO also provides schools with scientific experiments, while a student research scheme allows senior secondary students to work with a scientist on a project, and CREST awards are given every year to students completing experimental science or technology projects. The United Kingdom, in a programme launched in 1994, has also established CREST awards and Young Engineers Clubs, in order to involve schoolchildren in practical projects in collaboration with scientists and engineers from industry.

Box E. Proposals for reforming Japan's university curriculum

◊ Undertake quantitative and qualitative restructuring of S&T fields in universities, by updating and upgrading faculties and departments.

◊ Reform university curricula by introducing a mini-thesis early in undergraduate education, seminar-type classes, tutorials, multi-disciplinary supervision, laboratories where students do experiments, and a broader curriculum that gives S&T students a sound foundation in other disciplines.

◊ Improve the environment for research and teaching at graduate schools by increasing the number of fellowships, scholarships and student loans and having graduate students work with teaching staff on research and supervision of students.

◊ Improve university premises and facilities by providing space for research, setting up university museums and creative work studios which would also be open to non-students.

◊ Change the university entrance examination by abolishing selection based solely on the amount of knowledge acquired and including interviews, recommendations, essays, etc.

◊ Provide opportunities for young people to study S&T subjects through laboratory open houses, etc.

BEYOND THE EDUCATIONAL SYSTEM

Beyond the efforts made for education, initiatives are being taken on a number of fronts to make both the general public and young people in particular more aware of and more competent in science and technology and related policy issues. They involve government, non-government organisations (*see* Box F), the scientific and educational communities, business enterprises and the media. Many of the promising directions that are being explored are described below. Science museums and science centres are making use of the new media and new concepts of learning and design to create scientific exhibits that "speak", sometimes literally, to visitors. Science days or weeks are being organised, on a national or a local basis, while travelling exhibits go to regions without easy access to museums or exhibits. The media, particularly television, are being called upon to produce informative science programmes, and other electronic media, notably the Internet, are also being explored as vehicles for developing greater interest in science and technology.

Science museums, science centres

In many countries, dusty science museums filled with display cases have given way ***to science centres that make use of new media that appeal to the senses, stimulate the imagination, relate science and technology to everyday life, and allow visitors to discover science and technology in ways that are both accessible and interesting to many different categories of visitors***. Such centres are most effective when they draw on the expertise of both researchers and educators and implicate both in a continual and mutual process of education. They are an effective means of helping to dissipate misconceptions of science or technology as boring, irrelevant or too difficult (Boxes G and H).

While science centres are a focus of activities for the general public, some also have extensive activities specifically directed to school-age young people. France, which has two prestigious centres in Paris, the *Cité des Sciences et de l'Industrie* and the Natural History Museum, is now improving regional centres and theme parks, such as Oceanopolis, in Brest, and planetariums. Italy has begun the MUSIS project, a group of about 100 poles in and around Rome, many of them located in schools, which aim to make scientific culture and information available to the public, particularly to young people. It also has a newly inaugurated Science Centre in Naples, as well as science museums in Milan and Florence. In Japan, a government programme supports 302 science museums to improve exhibits, hold lectures, organise exhibits, etc.; the National Science Museum has a special multimedia exhibit. In the Netherlands, a large national centre, newMetropolis, has been built in Amsterdam, with support from government, industry and the municipality. It opened its doors in June 1997.

Box F. The Royal Society of New Zealand and S&T outreach

The Royal Society of New Zealand is a non-governmental body with statutory responsibility for promoting and supporting public understanding of science. It has an active programme in communicating science and technology to the public, especially to young people. It manages the Investigate programme and the national Science and Technology Festival, both of which are privately sponsored. In addition, under its aegis, the BP Technology Challenge promotes enjoyment of innovative technology. Up to 75 per cent of all schoolchildren are involved in these three programmes, and the 10- to 14-year-old group in particular has responded very well. Moreover, the Crest (Creativity in Science and Technology) programme is well established in secondary schools, and the LEARNZ study programme links schools and personnel in Antarctica over the Internet.

The Society also produces a range of materials: the Alpha series (information on S&T topics), the Beta series (issues in S&T), the Gamma series (the science behind the news), and the Delta series (pre-planned work units for teachers). The first three were originally aimed at secondary schools but now address the general public. Because these publications contain up-to-date information, are closely linked to the curriculum, are written in collaboration by scientists and teachers, are attractively presented with worksheets, and are cheaper than commercially produced materials, they have been very successful.

The recently inaugurated Science and Technology Festival offers communities an opportunity to learn more about New Zealand’s science and technology. Programmes are developed and directed by the communities but receive some support from the Society. One of the objectives is to involve audiences not traditionally associated with science and technology.

Science centres (and museums to a lesser extent) play an important role in promoting S&T in the main centres, with hands-on, interactive exhibits. In addition, a national Technology-Science Road Show tours the country annually, spending from three to five days in each location.

Some industries and business organisations provide materials that promote science. In addition to the BP Technology Challenge mentioned above, some make resource materials available to schools. For example, a conglomerate of forestry industries produced a major series on forestry. What is important is ensuring that the materials are linked to the curriculum and that teachers are involved.

Box G. Italy's Laboratorio dell'Immaginario Scientifico in Trieste

In Italy, the Laboratorio dell'Immaginario Scientifico (LIS), which operates in Milan, Florence, Rome, Naples and Trieste experiments with new methods of communicating science to children and adults. Prestigious scientists and active researchers give workshops or conferences on socially relevant issues. LIS also interacts with the International School for Advanced Studies for its Master's degree on Scientific Communication. LIS also presents information regularly in a local newspaper and publishes a series of books for the general public on significant scientific issues and their cultural implications. It has extended its audience through its presence on the Internet.

Its teaching service provides activities for primary and secondary schools, and its Children's Library gives children practical lessons in how research is done. LIS also has an interactive laboratory exhibit, "Beyond the Mirror" which uses semitransparent mirrors to teach about geometry, a microscope laboratory, a planetarium, and the "Experimentoteque" with materials for experiments in scientific subjects. Schoolchildren respond particularly well to presentations by experts and active researchers who, in conjunction with science teachers, transform passive-non-critical learning about science to active-critical learning, and to interactive exhibits that combine the expertise of teachers and researchers. Recent interdisciplinary trends (cognitive sciences, cosmological science, life sciences) seem to have particular appeal.

Over its ten years of existence, LIS has understood that informing and interesting the public is a difficult task which requires adopting a range of communication techniques: visual (TV, video, CD-ROM); conferences by experts and public discussions among scientists and with the public; interactive exhibits. All aim to enhance people's natural curiosity and induce them to seek further information in the written texts that remain the principal means of communicating information.

Among LIS's projects is one is to choose the best physics experiments from schools throughout the world, a project which would also make it possible to compare different teaching philosophies. Another plans to link schools on line, so that students in different schools can engage in research on topics of interest to them, such as social and environmental issues. LIS is also active in European activities involving science museums and has very good channels of communication with the scientific communities of the Third World, where public understanding of science and technology is particularly lacking and needs to be improved.

Box H. Sweden's Teknikens Hus in Lulea

Science centres need not be prestigious national institutions or extensive operations in order to interest children and the general public in science and technology. Sweden has a number of small science centres that vary considerably in terms of concept and content and depend on the enthusiasm and creativity of a few dedicated people, with the support of local authorities and enterprises and universities. They tend to reflect local interests and can become focal points of local society. This opens up possibilities for working with schoolchildren in classes to supplement school teaching, for training teachers for teaching technology, for co-operating with local industries for funding and support and for interacting with researchers at local universities.

Lulea's Teknikens Hus in northern Sweden displays the technology of regional industries and of everyday life. Industrial enterprises have donated both material and substantial sums. The exhibit hall has full-size and model exhibits on drilling equipment, steel making (with a model blast furnace), hydroelectric energy production (with the possibility of controlling a small but working power station), a full-size logging machine, an aeroplane cockpit, etc. It also presents the everyday technology found in people's houses in order to make them aware of how technology contributes to daily life.

The centre co-operates with local schools and teachers to use the cold winter climate, for instance, to team-teach science and technology through experiments. Students measure wind, temperature, depth of snow and ground frost to see the connections and their role in total climate; they try to find out how and why clothing or insulation protect against the cold. Skating or skiing are excellent examples of friction, and constructing roofs strong enough to hold loads of snow teaches about stress and strength of materials. This makes it easy to move from reality to scientific principles and to see why science and technology are important. Outreach activities include small exhibits for teaching purposes and advice and tips to teachers through newsletters and computer networks. Teknikens Hus is particularly concerned with encouraging interest in technology among girls and women. All of its educators are female and act as role models. One apparent result of the centre's activities is the fact that the number of girls entering secondary-school science programmes is higher in Lulea than in comparable cities in northern Sweden that lack a science centre.

Attendance at the centre is high. Entries in 1996 exceeded 175 000 and have exceeded 165 000 for the last four years (Lulea has 70 000 inhabitants and the region as a whole 260 000). Clearly, visitors come several times, and schoolchildren who come for school activities return with parents and friends.

Science festivals

Most countries sponsor science fairs in the form of science days, weekends or weeks. In France, “Science en fête” (festive science) has been an annual weekend event since 1992. It is organised as a local initiative, in various French cities. In 1996, almost 10 000 scientists and engineers participated, while visitors numbered some 4 million at almost 2 000 different sites. The events depend on local possibilities: visits to scientific or technological laboratories, to plants, to observatories; hands-on experiments and demonstrations in various public places; plays and shows; scientific movie festivals; competitions on scientific topics.

Encouraged by the French example, major science organisations in Germany have organised “Tage der Forschung” (Days of Research) since 1994, with more than 300 events taking place all over the country in 1997. The events are listed in a single calendar; however, they are organised locally in some 100 towns from Aachen to Zittau. In 1997 a central event is scheduled as well, where the Federal Chancellor will deliver an address to the public.

Belgium has recently introduced a Flemish Science Week, with various components targeting different segments of the population. Hungary organises regional innovation days, which take place monthly in different cities. For several years, Italy has had a broadly co-ordinated science week involving some 1 000 activities organised by universities, research centres, museums and schools. Japan has had an annual science and technology week for longer than most countries (the 37th was held in 1996) with up to 700 events; unfortunately, opinion polls indicate that 87 per cent of the public is unaware of the event.

The US National Science Foundation has organised an annual science and technology week since 1985, with support from corporate sponsors; it makes a special effort to interest girls, women and minorities, groups that have traditionally been under-represented in science, engineering and technology. Norway’s Research Council has introduced an annual autumn science week, and Mexico has also recently established a science and technology week.

The Netherlands’ national science and technology week, started in 1986, is supported by government, industry, a number of scientific institutions, universities, research laboratories and museums. Overall, some 200 organisations are involved, and media coverage is extensive. In 1996, about 350 000 people, schoolchildren and members of the general public, participated in some way or another in the activities organised.

In Korea, April is science month and most S&T awareness activities take place then, organised by the Ministry of Science and Technology with the co-operation of the Korea Science Foundation, among others. Primarily directed to young people, it has about 500 events and about 12 700 students participate nation-wide.

The United Kingdom has also begun an annual week devoted to science, engineering and technology, co-ordinated by the British Association, with funding support from the Department of Trade and Industry's Office of Science and Technology. In the second of these, more than 600 000 people of all ages attended some 1 100 events throughout the United Kingdom, and millions more heard or watched special programmes on BBC radio and television.

Travelling exhibits

Several countries organise ***travelling exhibits in order to reach populations that are less likely to seek out or to have access to science centres, festivals, etc***. In New Zealand, for example, with the decline in government promotion of science and technology since the early 1990s, it has largely fallen to interested organisations to promote public interest in S&T. Government funding has generally been quite limited, except when the government's objectives are not being met, in which case transitional funding may be provided. As a result, the Royal Society has made noteworthy efforts in this area (*see* Box F above).

In France, the French ministry in charge of scientific research has offered scientific activities to vacationers in vacation clubs and camps. In 1990, a theatre programme on astronomy and astrophysics was presented in several centres. There were also several exhibits and hands-on experiments, as well as lectures with films and slides on volcanoes, astronomy and the environment. In 1991, 12 vacation centres proposed scientific activities in addition to sailing or water games, and a caravan with experiments on optics, lasers and holography travelled to various vacation sites. Since then, more and more leisure villages or camps, both commercial and non-profit, have been involved, and three trailers have travelled to various tourist areas. Since 1995, this programme has been extended to socially deprived areas (leisure centres, swimming pools, sport centres), with workshops on physics, chemistry and ecology. Interest in this initiative is growing. Financial help comes from savings banks and various foundations. In 1996, more than 50 000 people were involved.

ECSITE is organising international travelling exhibits which will tour several European countries. ECSITE is an association which co-ordinates European, hands-on, science centres. The next major exhibits will be on chemistry and mathematics.

The media

As opinion surveys in all countries show, ***the media*** – newspapers, magazines, radio, the electronic media and especially television – ***are the principal vehicle for disseminating information about science and technology to the general public***, although the use made of them varies greatly among countries. While the media are a powerful force for disseminating information to the general public, the art of stimulating the imagination often remains elusive. It is important to use television, and the new electronic media in particular, in ways that engage viewers and users, notably by taking a narrative approach and beginning from concrete every-day elements and gradually introducing more and more complex and abstract concepts, using all the possibilities offered by the media to make them clear (*see* Box I). In presenting scientific discoveries, it is important to show the mystery and the drama of scientific discovery, as well as the end results. This is a difficult task, and an area where much progress can be made.

Box I. An Internet-linked international television channel?

For the past 20 years, an international scientific audio-visual conference sponsored by UNESCO and France's CNRS (Centre national de la recherche scientifique), called "Image and Science", has been held every year in Paris. It has made clear that it is not a simple matter to interest the public in science through audio-visual productions. The key to success is to take full advantage of the most popular television formats (news, dramatic presentations) and to adopt an effective means of communication (essentially narrative). The suggestion has been made to create an international education and training television channel or to make joint use of certain niches on thematic and cultural channels and attaching an Internet server in order to allow for dialogue among viewers and the creators of the programmes, among whom it is important to include scientists and educators.

In recognition of the importance of this means of communication as a way to raise the public's interest in science and technology, Japan has decided to create a television channel with programmes around the clock on science and technology, to extend broadcasting of the University of the Air nation-wide, and to exploit all media possibilities, including multimedia.

Other countries are actively seeking to increase the visibility of science and technology in the media. France has made available various incentives to encourage the development of scientific programmes for national television channels, and more innovative programmes are being proposed. Italy's National Research Council, in co-operation with television stations, produces science programmes for the general public, such as programmes on earthquakes and strategies to reduce risks.

Mexico's National Council of Science and Technology (CONACYT) has reached an agreement with the media whereby space is reserved free of charge for programmes sponsored by the Council, which can later be lent to primary and secondary schools for educational purposes. Some of the programmes involve debates on scientific issues or short capsules presenting remarkable scientific facts. The same type of agreement has been reached with the radio stations.

The Czech Republic, for its part, held the 33rd annual international Techfilm festival in 1996. It focused on technology, agriculture and ecology and presented 30 films. Over the years, more than 3 300 films have been entered, and 2 000 have been shown. The festival stimulates discussion among film and television artists, scientists, teachers and the general public.

Nonetheless, the problem of gaining more of the public's attention remains. An Australian survey notes that such subjects receive only a quarter the space of business or sports in newspapers, and in Austria only three or four newspapers (out of 12) have regular "science pages", and these are oriented to already interested and well-informed readers. In Korea, television programmes devoted to science and technology are scheduled for off-peak viewing time. Austria only presents foreign series on publicly owned television: there are, however, informative and well-structured radio reports daily (which last 30 minutes and are aired at 19.00), although they reach only some 4-6 per cent of the population. The Swiss media tend to take a sceptical or critical view of science and technology, especially in the German-speaking parts of the country, and, unlike most countries, Switzerland does not have a specialised science review.

Forums for dialogue

Research and technology often confront society with possibilities that require democratic reflection on the ethical and social consequences. Ethics applies to all fields, and recent attention to the credibility of scientific advice and information in public debate (e.g. the dumping of the oil rig Brent-Spar, mad cow disease) draws attention to the need for the highest standards in areas such as health care and the environment, given the substantial influence that research has on political decisions. As the latter are more and more based on research, the line between the world of research and politics is becoming harder to draw.

If the public is to have confidence that research can contribute to a better society, better interaction between scientists and the public and better dissemination of results will be essential. Researchers will have to make a serious effort to predict the possible risks that their research may present to society and the environment. More generally, efforts should be made to improve public understanding and awareness of scientific and technical issues, researchers should be made more aware of their special responsibilities as experts, and politicians should improve their ability to make use of scientific advice and information.

All countries need to foster the development of forums for dialogue between government authorities, scientists, and the general public and its representatives on issues of science and technology. Such institutions can take many forms, depending on the country's structures and traditions. They may foster discussion of the choices to be made in terms of research and development, as in Denmark, for example, where the government has decided to draft a national research strategy through an open process in which scientists, industrialists, organisations, politicians and ordinary people discuss needs and possibilities. The choices made are therefore envisaged as a social contract between the political system and the science community and reflect the view that S&T policy should not be decided by bureaucrats and experts alone.

Many countries have recognised the need to involve the public in questions concerning the ethics of scientific research and its applications. The Netherlands has undertaken a pilot project for a national platform for science and ethics, which experiments with different types of public debate, and discussions have been held with scientific and professional organisations concerning ways to make their members more sensitive to the social and ethical dimensions of their work. Denmark has also addressed the need for better interaction among politicians, scientists and the public by establishing the Danish Council of Ethics and a Committee System on Scientific Ethics. The former informs the public and advises the government on questions of ethics and biomedicine in general, while the latter, which includes both laymen and researchers, must approve all Danish biomedical research projects involving experiments with human beings.

Recognising the importance of finding qualified interpreters able to present such information to these different groups, the Japanese government has decided to launch a broad effort to use researchers, educators and journalists as "interpreters of science", in order to foster better communication with science and society (*see* Box J).

Those who are able to "interpret" science and technology to the public, starting with the researchers themselves, should have incentives to do so and their efforts should be publicly rewarded. In Australia, for example, the Daley awards for journalism are national awards for excellence in communicating science, technology and engineering issues to the public via print, radio and TV, features and news, and photography, and there are special awards for journalists under 26 years of age. In the case of scientists, it is essential that their efforts be taken into account in terms of professional advancement.

Continuing involvement and dialogue about science- and technology-related issues are indispensable not only for the continuing vigour of the scientific enterprise itself, but also for the social and economic vitality and well-being of economies and societies throughout the world.

Box J. Japan's programme for "interpreters of science"

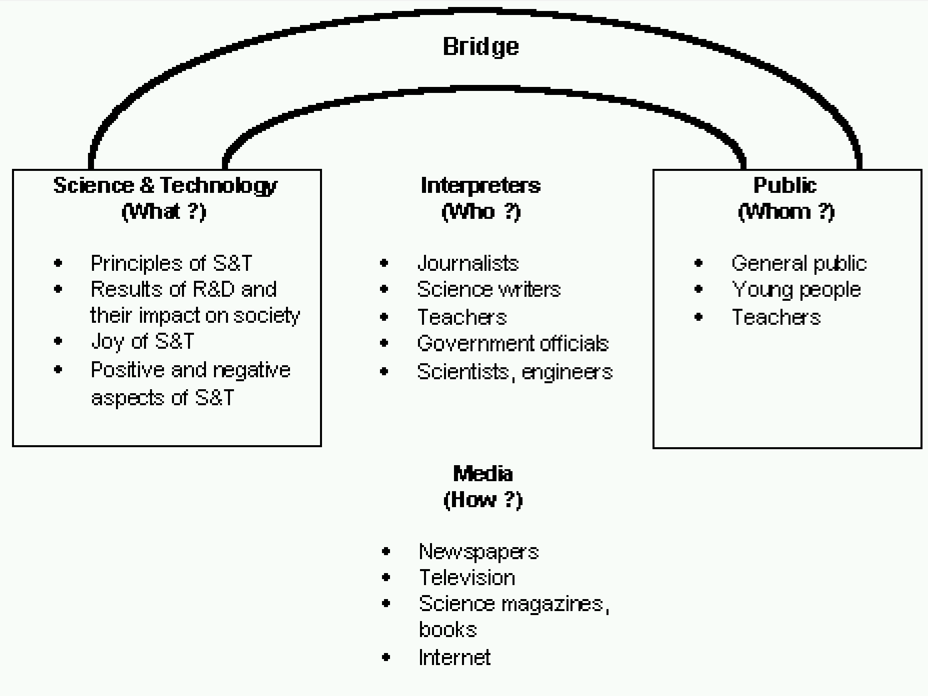
◊ Expanding opportunities for interpreters' activities, including greater use of mass media, such as TV, radio, newspapers and magazines. Also under consideration is the establishment of a science and technology television channel and a plan to send more scientists and engineers to schools, to open research institutes more often to the public, to expand science camps for high-school students at research institutes, and to increase activities at science museums.

◊ Training interpreters of science so that scientists are better able to communicate to non-specialists and organising lecture programmes where scientists present recent advances to journalists and school science teachers.

◊ Establishing a commendation system, so that distinguished interpreters will receive recognition for their achievements from the Minister for Science and Technology.

◊ Promoting interactive communication over the information network by developing an interactive database for answering questions commonly asked by young people, a database with information on research topics in various institutes and virtual science museums that can be accessed from the home.

The role of interpreters



LOOKING TO THE FUTURE

What more needs to be done? What needs to be done better to improve education and motivation, to encourage dialogue and engagement? These are the questions that concern policy makers today. The following areas might usefully be targeted in order to improve scientific literacy and better integrate science and technology into the knowledge-based society:

◊ ***Early education***: The importance of early education to scientific literacy and to interest in science and technology has been demonstrated. Governments should therefore consider means to ensure better involvement of teachers, improve student motivation, and implement teaching methods based on concrete, "hands-on" learning.

◊ ***Life-long learning***: Continuing advances in science and technology mean that citizens need to keep abreast of developments and to maintain their interest. More extensive annual science weeks, as well as science museums and science centres with stimulating exhibits elaborated in collaboration with educators and scientists, using the latest possibilities offered by the new media, need to be developed.

◊ ***Effective mass media*:** The effectiveness of the mass media, particularly television, in increasing awareness of science needs to be assessed, with a view to developing attractive, useful materials with genuine scientific content. The potential of the Internet also needs to be harnessed.

◊ ***Forums for dialogue***: Appropriate institutional arrangements for enhancing public dialogue on science- and technology-related issues, including ethical questions, need to be established or extended.

◊ ***International co-operation***: All countries can gain from the exchange of high-quality materials (television programmes, exhibits, etc.), as well as from the exchange of types of efforts that have proved successful. It is important to involve scientists and citizens in less developed countries as well, in activities related both to improvement of primary education in science and to awareness among the adult public, particularly in areas of global interest such as the environment.

There is no doubt that motivation is the primary factor in increasing interest in science and technology. It is obvious that people of all ages learn more easily about any topic, even a very complex one, when they are directly and personally involved. For example, in the face of illness, they quickly learn, and understand, even extremely subtle physiological mechanisms and relevant scientific information. In seeking to help improve scientific literacy, it is therefore necessary to address not only the intelligence but also the imagination and the emotions, in order to make science and technology understandable, as they are only when one has understood that one can make a valid contribution to discussions of science and technology.

Scientists and engineers

Scientists and engineers should engage actively in public debate about their professional work, both directly and by contributing to the activities of professional interpreters and educators. They should discuss their work and its possible social implications in language that is easy to understand and with a minimum of scientific terminology. They should recognised the validity of informed public attitudes towards specific aspects of their work that may not fully accord with prevailing scientific consensus or industrial preferences.

They should endeavour, through both formal teaching and informal outreach activities, to stimulate young people to explore the frontiers of knowledge, in recognition of the fact that the next generation must continue to advance those frontiers.

They should receive recognition from their peers that public outreach activities involving their work and their discipline are of value, and these efforts should be rewarded in terms of career advancement. As their involvement in such activities is essential, it should be recognised that they may require training in order to participate more effectively in public awareness efforts.

The scientific community should be well informed about the possible ethical and social impact of scientific research and new technologies, sensitive to public concerns and prepared to discuss the ethical issues.

The public

Instead of simply accepting or rejecting new developments in science and technology, ***individual citizens have an obligation to gain sufficient knowledge and understanding to express their concerns rationally***. They have the right, no less than the responsibility, to express and discuss their concerns, even when they appear to conflict with accepted scientific viewpoints.

Because science and technology contribute to social development and stability, they are the common assets of humankind. Therefore, the public also has a responsibility to nurture skilled human resources able to continue to ensure scientific and technical development.

The media

Beyond providing appropriate information in response to public uncertainties and concerns associated with science and technology, ***the media should encourage and facilitate public debate*** and help scientists and engineers understand the origins and character of public concerns.

The media will increasingly be expected to act as interpreter, conveying specialist knowledge to the public in an easily digested form. While such information will of necessity be cast in accessible, non-scientific language, particular care should be taken to ensure that it is accurate and to point out clearly scientific and technical uncertainties and points of contention if and when they exist.

It is important to disseminate methods of scientific thinking based on critical analysis and continual questioning as well as scientific knowledge. This will improve understanding of research, as well as what can be expected from scientific research, including both its hopes and its limitations.

Governments

Governments should support the building and networking of interactive science centres and museums, the establishment of structural links between these institutions, schools and universities, and support volunteers working in the field of science popularisation. They can also encourage the exchange of high-quality science and technology television and video programmes and the dissemination of scientific and technical information over the Internet. They should also promote international co-operation in line with the ongoing globalisation of information.

Political leaders themselves, as well as technical and administrative managers, need to understand what is at stake in decision making requiring scientific expertise. Decision makers, like the public at large, need to understand not only scientific facts, but also the scientific method (hypothesis, testing, experimentation, validation).

The processes involved in science and technology policy formulation must be transparent. Mission-oriented research involving large groups of scientists or engineers and requiring substantial public funding should be based on public consensus, and suitable techniques for evaluating public research and development activities should be developed.

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Education should provide young people with opportunities to learn the intrinsic value of science and technology and the scientific way of thinking through practical experience and experimentation. It is vital that young people with the potential to become productive scientists recognise the joys of scientific knowledge and creativity. More generally, young people will need to have basic notions of science and technology, in view of their increasing importance for entering the job market and meeting the demand for increasing levels of technical skills. Special attention should be paid to the important role of teachers and curricula, together with parents and local communities, so that students retain the interest in science and technology developed during their formative years. Supporting teachers in developing new approaches to teaching and learning at both the primary and secondary levels is crucial.

As ethical issues become more complex and more evident, particularly in the biomedical sciences, greater efforts to promote public dialogue will be needed to deal with society's legitimate concerns about the science and technology enterprise.

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