Encouraging Student Interest in Science and Technology Studies

Global Science Forum


STUDENT CHOICES SCIENCE CAREERS EDUCATION STUDENT CHOICES SCIENCE CAREERS EDUCATION STUDENT CHOICES SCIENCE CAREERS EDUCATION

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Foreword

The evolution of student enrolments in science and technology at various levels of the education system has been an issue of considerable interest in many OECD countries over recent years, given that the economy is increasingly driven by complex knowledge and advanced cognitive skills. Some countries are worried that, given future demand for skills, not enough young people are interested in studying science and technology, a view summed up by the US National Science Board:*

If the trends identified in Indicators 2004 continue undeterred, three things will happen. The number of jobs in the US economy that require science and engineering training will grow; the number of US citizens prepared for those jobs will, at best, be level; and the availability of people from other countries who have science and engineering training will decline, either because of limits to entry imposed by US national security restrictions or because of intense global competition for people with these skills. The United States has always depended on the inventiveness of its people in order to compete in the world marketplace. Now, preparation of the S&E workforce is a vital arena for national competitiveness (NSB, 2004).

The Global Science Forum authorised an activity on the subject at its Ninth Meeting in July 2003. This issue was identified as an OECD priority as a result of the ministerial meetings of the OECD Committee for Scientific and Technological Policy (January 2004), and of the Education Committee (March 2004).

Based on the recommendations of a steering committee (chaired by Professor Jean-Jacques Duby of France), presented at the Global Science Forum meeting in July 2004, a working group was established, composed of representatives from 16 countries, the European Commission and the OECD Secretariat, and chaired by Professor Sjoerd Wendelaar Bonga of the Netherlands. Statistical data on student enrolments and graduation rates were submitted by 19 countries, and analysed together with information on factors contributing to possible declining interest and solutions attempted in different countries.

The Working Group's preliminary results and recommendations were presented and debated during an international conference co-organised by the OECD Global Science Forum and the Ministry for Education, Culture and Science of the Netherlands in Amsterdam on 14-15 November 2005.

The present report summarises the main findings and recommendations from the working group following this conference and presents detailed analyses of the statistical data, causal factors, and solutions implemented or proposed by various countries.

The overall goals of the Global Science Forum activity were:

1. *To analyse quantitative trends in enrolments in S&T studies during recent years (and, in particular, to quantify the extent of any decline).*
2. *To identify the underlying factors that affect students' choices.*

* For the sake of convenience, "science and technology" is used throughout the present report to designate science, technology, engineering and mathematics.

3. *To explore solutions that can be implemented to influence such choices.*

Secondary goals were to identify the limitations of the existing indicators and models of the complex phenomena involved, and to explore the need for extended data and information sharing.

The study did not address the potential impact of a decline on national economies and on society in general, nor the relationships between supply and demand for S&T students.

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Executive Summary

An understanding of science and technology is necessary not only for those whose career depends on it directly, but also for any citizen who wishes to make informed choices about many controversial issues being debated today. Recently, a number of countries have expressed the fear that interest in S&T is declining, even as demand for S&T graduates grows. The Global Science Forum was asked to investigate whether this decline was really happening, and to analyse the reasons for students' choice of study and career as well as possible action.

The increase in numbers of Science and Technology students in recent years hides a decrease in share

While absolute numbers of S&T students have been rising as access to higher levels of education expands in OECD economies, the relative share of S&T students among the overall student population has been falling. This is true not only in tertiary education, but also for upper secondary in several countries. Coupled with unfavourable demographics and a stabilisation of the number of students accessing tertiary education, several OECD countries can expect this general trend to affect the *absolute* number of S&T students in future years. In other countries, a demographic recovery would mitigate this trend.

Aggregate numbers hide important differences among disciplines. Engineering students account for 40% to 60% of S&T students in most countries, especially at the new entrant and graduate levels, and are characterised by a stable or positive enrolment trend. For physical sciences and mathematics, however, the absolute number of students often shows a decline. Life sciences' share has remained mostly stable due primarily to an increasing number of female students, while engineering benefits from the perception that job prospects are good. The number of computer science students has increased dramatically, perhaps reflecting shifts in student choice within S&T, *e.g.,* away from physics.

Recommendations

Given that enrolments are declining in certain fields while student numbers in higher education is expected to stabilize, governments of OECD countries may require a better understanding of the impact of this phenomenon on their economies and on society in general. This analysis should be followed by a complementary effort to understand future demand for S&T graduates at all levels.

Women are still strongly under-represented

Female students are the most obvious resource for increasing S&T enrolments, along with young people from minority groups to some extent. Young female students suffer from stereotypes in relation to the expectations of parents, teachers, and society in general, despite doing at least as well as boys. The teaching process tends to reflect the same stereotypes. Girls tend to undervalue their own performance, and hence their ability to pursue S&T. They also lack role models. In certain respects, these issues also arise for students belonging to some minorities, although socio-economic considerations, as well as differences in cultural and environment factors make for complex and difficult analyses and solutions.

Furthermore, girls tend to show a stronger interest in people than facts or "things", and these differences are amplified in the way S&T are taught, and in the perception of S&T careers. Rethinking education to offer equal opportunity seems necessary, but no consensus has yet emerged concerning the assumptions, methods, or results that can be achieved. Therefore although the number of female students in tertiary education has increased more rapidly than males, the proportion of women choosing S&T studies is still lower than that of men. Moreover, trend analysis suggests that the proportion of female S&T graduates may hit a 40% "glass ceiling", perhaps due to a selective choice of females for specific fields.

Recommendations

Governments should actively promote equal opportunity for students, and should take steps to eliminate negative stereotypes, to allow all students to achieve their full potential, without subtle or overt discrimination. The learning context and approach should be modified to make them more attractive to female students, and mentoring projects should be encouraged to support women and minority students undertaking careers in S&T.

Scientists have a positive image, but S&T professions are less attractive

Choice of study is determined by a range of factors combining objective and subjective, conscious and unconscious influences ranging from family background to salary expectations to happy or unhappy experiences at school. In addition, changes in the general context of our society, such as the intensifying and accelerating globalisation, also has an influence, *e.g.* young people may choose broader types of curriculum with a wide range of disciplines to adapt to the job market.

While young people generally have a positive view of S&T and its contributions to making life better, the image of S&T as a profession is largely negative. In spite of this, most adults would still recommend a scientific career to their children or to a young relative. When young people are asked to list their criteria for choosing a profession, they first cite passion/interest, then working conditions, income, and security/stability. On these criteria, a career in S&T can seem less attractive than more fashionable professions thought to have a more stimulating lifestyle, such as the media.

Having a parent or family member working in S&T increases the chance of a student choosing S&T and professional contacts have a strong impact on career choices, especially for girls who often lack role models.

Government action and undertakings by scientific organisations often target the image of science and scientists, but communication tends to focus on science itself, not on the reality of S&T professions. The actual impact of the various actions on both young people's attitudes and their choices of studies or careers is poorly evaluated.

Recommendations

Provision of accurate and unbiased information is an important aspect of any policy to increase the attractiveness of S&T studies and careers. Such information should not only be made available to students but also to the education community and parents. Governments should provide resources to support such actions, and the various stakeholders should establish networks to share information on best practices and establish the necessary evaluation tools.

Curricula need to be reformed, and special attention paid to 15-year-old

Educational content and curricula play an important role in raising and maintaining young people's interest in S&T. Positive contacts with science and technology at an early age can have a long-lasting impact while negative experiences at school, due to uninteresting content or poor teaching, are often very detrimental to future choices. Furthermore, curriculum structures can also play an important role in preventing pupils from pursuing their natural preferences. Thus, declining enrolments are often attributed to the uninteresting and difficult content of science courses, with disciplines with high theoretical content such as mathematics, physics and chemistry suffering most, while newer, more fashionable subjects are seen as easier, more interesting and offering better job prospects.

Despite children's natural curiosity for science and technology in primary school, many of their teachers are uncomfortable with science subjects and with hands-on demonstrations. Later on, pupils need to feel the relevance of the subject to society and to their own world. Unfortunately, what is taught is often disconnected from cutting-edge science and from today's applications of S&T, and tends to dampen the interest acquired at a younger age. Interest in S&T is observed to decline most sharply around age 15. This is also when gender differentiation starts to translate into choices, and when key future orientations are set. Regrettably, curricula are often too rigid to allow those pupils that do not choose to follow S&T fields as their primary subjects to come back to science at a later stage. Over-specialisation and the lack of social dimensions in the curriculum can also deter students from pursuing tertiary S&T studies.

Recommendations

Curricula should be redesigned to provide more attractive and relevant contents, particularly in secondary education. Teaching should also concentrate more on scientific concepts and methods rather than on retaining information only. At tertiary level, professional skills and cross-disciplinary studies should be promoted. Curricula also need

to be more flexible to offer a second chance to students who wish to come back to S&T studies following a different choice at an earlier stage.

Teacher training and qualification requires attention

Teachers frequently report a lack of resources and opportunities to reflect upon their way of teaching and to increase their knowledge. In many countries, most primary teachers come from a non-S&T background, and many have not had any specific professional training in S&T. This can also be true in secondary education if teachers are required to teach subjects for which they lack competence.

Further training on recent developments is often lacking or does not focus on theoretical subject content. As a result, and despite the fact that they are often very motivated by their work, many S&T teachers may need to update their knowledge and may not be at ease with the developments which most interest students. Scientific careers are evolving rapidly as well, but most teachers do not have access to information on career prospects for S&T students and are therefore reluctant to offer career advice.

Teachers are often recruited on the basis of S&T competence, not in teaching as such. In many countries, recruitment does not include any requirement or further training in teaching skills. The problem is especially acute in tertiary education, where teachers are usually only evaluated on their research performance, which may lead to high drop-out rates.

Recommendations

Governments and relevant institutions should provide adequate resources for teacher training and classroom activities, and rewards provided to teachers who make the effort to upgrade their skills and knowledge, or invest their time in S&T communication. Specific information should also be provided to teachers in their initial training, to limit the transmission of stereotypes to pupils, and particularly to female and minority students. Teaching would also benefit from exchanges of information and best practices on S&T studies between teachers from primary to university level.

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Synthèse (en français)

La maitrise des sciences et technologies est nécessaire non seulement pour ceux dont la carrière en dépend directement mais aussi pour tous les citoyens qui sont amenés à prendre des décisions éclairées sur de nombreux sujets controversés qui font débat aujourd'hui. Récemment, un certain nombre de pays ont exprimé leur préoccupation *vis-à-vis* d'un certain désintérêt pour les S&T, alors même que la demande pour des diplômés dans ces domaines continue de croitre. Le Forum mondial de la science a été chargé d'enquêter pour déterminer si un recul réel pouvait être mesuré et pour étudier les causes de ce phénomène ainsi que les solutions envisageables.

L'augmentation du nombre d'étudiants en sciences et en technologie ces dernières années cache une baisse en terme proportionnel

Tandis que le nombre absolu d'étudiants en S&T croissait à la suite de la forte progression du taux de scolarisation dans l'enseignement supérieur au sein des économies de l'OCDE, la proportion d'étudiants en S&T accusait une baisse régulière au cours de la même période. Conjuguée à une évolution démographique défavorable et à une stabilisation du nombre d'étudiants accédant à l'enseignement supérieur, cette tendance générale dans plusieurs pays de l'OCDE risque d'avoir une incidence sur l'effectif d'étudiants en S&T en chiffres absolus dans les années à venir. Dans d'autres pays, une reprise démographique pourrait atténuer cette tendance.

Les chiffres globaux masquent d'importantes différences entre les disciplines. Les étudiants en sciences de l'ingénieur représentent entre 40 et 60 % des étudiants en S&T dans la plupart des pays, sauf au niveau doctorat, et leur scolarisation suit une tendance stable ou positive. La situation est inverse en sciences physiques et en mathématiques pour lesquels on constate souvent une baisse de l'effectif d'étudiants en chiffres absolus. La proportion des étudiants en sciences de la vie est en général restée stable en raison principalement d'une progression de l'effectif d'étudiantes en sciences de la vie, tandis que les sciences de l'ingénieur bénéficient d'une image positive au niveau des perspectives d'emploi. Le nombre d'étudiants en informatique a progressé de façon spectaculaire, reflétant peut être une réorientation des choix de certains étudiants au sein même des S&T, par exemple des sciences physiques vers l'informatique.

Recommandations

Étant donné la diminution du nombre d'étudiants dans certains domaines des S&T tandis que le nombre global d'étudiants dans le supérieur à tendance à se stabiliser, les pays de l'OCDE pourraient bénéficier d'une meilleure connaissance des répercussions que

pourrait avoir l'évolution actuelle des effectifs d'étudiants sur leur économie et sur la société en général. La présente analyse devrait être suivie d'un effort complémentaire pour mieux comprendre l'évolution de la demande future de diplômés en S&T à tous les niveaux.

Les femmes sont encore fortement sous-représentées

Les étudiantes constituent le gisement le plus évident pour accroître les effectifs en S&T, ainsi, à un moindre niveau, que les jeunes appartenant à certaines minorités.

Les jeunes étudiantes se heurtent à des stéréotypes par rapport aux attentes de l'extérieur (celles des parents, des enseignants et de la société en général), malgré des résultats aux évaluations au moins aussi bons que ceux des garçons. Les pédagogies tendent à refléter les mêmes stéréotypes. Les filles ont tendance à sous-évaluer leurs propres performances et, de ce fait, leur aptitude à entreprendre des études de S&T. Elles ne disposent pas non plus de modèles auxquels elles pourraient s'identifier. À certains égards ces stéréotypes s'appliquent aussi aux étudiants appartenant à certaines minorités, même si des considérations socio-économiques et les différences de facteurs culturels et environnementaux font que les analyses sont difficiles et les solutions complexes.

En outre, les filles tendent à s'intéresser bien plus aux personnes qu'aux faits ou aux « choses » et ces différences sont amplifiées par la façon dont les S&T sont enseignées, et dans l'idée que l'on a des métiers liés aux S&T. Repenser le processus éducatif pour assurer l'égalité des chances aux deux sexes semble nécessaire mais aucun consensus ne s'est encore dégagé concernant les hypothèses, les méthodes ou les résultats qui pourraient être obtenus. Ainsi, bien que le nombre d'étudiantes dans le supérieur ait augmenté à un rythme plus rapide que l'effectif masculin, en proportion, moins de femmes que d'hommes choisissent des formations en S&T. En outre, les analyses de tendance donnent à penser que la proportion des diplômées en S&T se heurte à un plafond autour de 40%, peut-être du fait que les femmes se montrent plus sélectives dans leurs choix pour certaines matières de S&T.

Recommandations

Les pouvoirs publics devraient activement favoriser l'égalité des chances et prendre des mesures pour vaincre les stéréotypes négatifs, afin de permettre à tous les étudiants de réaliser leur potentiel sans discrimination, ouverte ou insidieuse. Il convient de modifier les conditions et les méthodes d'apprentissage pour que les étudiantes les trouvent plus attrayantes, et des projets de mentorat devraient être encouragés pour aider les femmes et les étudiants appartenant à des minorités à se lancer dans des métiers dans le domaine des S&T.

Les scientifiques conservent une bonne image, mais les métiers des S&T sont moins attractifs

Le choix des études est déterminé par une gamme de facteurs combinant des éléments objectifs et subjectifs, conscients et inconscients, comme les antécédents familiaux aussi bien que l'espérance de salaire par exemple, ou le vécu à l'école. De plus, les changements dans le contexte général de notre société, comme l'accélération et l'intensification de la

mondialisation, ont aussi une influence, incitant par exemple les jeunes à choisir des filières plus générales pour s'adapter au marché du travail.

Si les jeunes conservent généralement une vision positive des S&T et de leur contribution à améliorer notre qualité de vie, l'image des S&T comme profession est largement négative. Malgré cela, la plupart des adultes recommanderait encore la carrière scientifique à leurs enfants ou à des proches. Lorsque les jeunes sont interrogés sur leurs critères de choix pour un métier, ils citent d'abord l'intérêt ou la passion pour le sujet, puis les conditions de travail, le salaire, et la sécurité/stabilité. Sur ces critères, une carrière dans les S&T peut paraître moins attractive que d'autres professions plus à la mode qui semblent être plus stimulantes, comme dans les médias.

Avoir un parent ou un membre de la famille qui travaille dans les S&T accroit les chances d'orientation des étudiants en faveur des S&T, et les contacts professionnels ont un fort impact sur le choix du futur métier, particulièrement pour les filles qui manquent de modèles.

Les actions des pouvoirs publics et organisations scientifique ciblent souvent l'amélioration de l'image des sciences ou des scientifiques, mais la communication tend à se concentrer sur la science elle-même, et non sur la réalité des métiers des S&T. De plus, l'impact réel de ces diverses initiatives sur l'attitude des jeunes et leur choix d'orientation ou de métier est rarement évalué.

Recommandations

La fourniture d'informations exactes et non biaisées est un aspect essentiel pour toute politique visant à accroître l'attrait des études et des métiers dans le domaine des S&T. Ces informations doivent non seulement être fournies aux étudiants mais également à tous les acteurs concernés (enseignants, chercheurs, parents, etc.). Les gouvernements concernés devraient allouer des ressources adéquates pour soutenir ces actions, et les différents acteurs concernés devraient s'établir en réseaux afin de favoriser l'échange d'informations sur les pratiques exemplaires et élaborer des outils d'évaluation.

Les curricula doivent être réformés, et une attention spéciale doit être portée autour des 15 ans

Les contenus d'enseignement et les programmes sont des éléments essentiels dans le développement et le maintien de l'intérêt des jeunes pour les S&T. Un contact positif avec les sciences et technologies à un stade précoce peut avoir un impact durable, tandis que des expériences négatives à l'école, en raison de contenus inintéressants ou d'un enseignement décevant, découragent souvent les jeunes à choisir un métier dans ces domaines. De plus, la structure des curricula peut aussi jouer un rôle important en empêchant certains élèves de suivre leurs préférences naturelles. La baisse des effectifs est ainsi souvent attribuée au contenu inintéressant et difficile des formations scientifiques, avec des matières au contenu très théorique comme les mathématiques ou les sciences physiques qui en souffrent le plus. Au contraire, des sujets nouveaux, plus à la mode, sont perçus comme plus faciles, plus intéressants, et offrant de meilleures perspectives de carrières.

Malgré la curiosité naturelle des enfants pour les sciences et la technologie à l'école primaire, de nombreux enseignants sont mal à l'aise avec les sujets scientifiques et les expériences pratiques. Plus tard, les élèves ont besoin de sentir l'intérêt que les disciplines scientifiques présentent pour la société et pour leur propre monde. Malheureusement, les savoirs enseignés sont souvent sans rapport avec la science de pointe ou avec les récentes applications des S&T, ce qui tend à amoindrir l'intérêt suscité à un âge plus jeune. On constate que l'intérêt pour les S&T baisse très fortement vers l'âge de 15 ans. C'est également l'âge auquel les distinctions entre garçons et filles commencent à se traduire dans les choix et lorsque les orientations essentielles pour l'avenir sont fixées. Or, et c'est regrettable, les cursus sont souvent trop rigides pour permettre aux élèves, qui n'ont pas privilégié les S&T dans leur choix initial de filières, de revenir à l'étude des sciences à un stade ultérieur. Une spécialisation excessive et l'absence de dimension sociale dans les programmes d'enseignement peuvent dissuader certains groupes d'étudiants d'entreprendre une formation supérieure en S&T.

Recommandations

Il faudrait redéfinir les programmes d'enseignement pour proposer des contenus plus attractifs et à la page, particulièrement dans l'enseignement secondaire. La pédagogie devrait en outre être concentrée plutôt sur les concepts et les méthodes scientifiques que sur la seule mémorisation de l'information. Dans le supérieur, l'acquisition de compétences professionnelles et les études pluridisciplinaires devraient être développées. Il faut aussi assouplir les cursus d'enseignement pour donner une deuxième chance aux étudiants qui souhaitent revenir à une formation en sciences et technologies après avoir fait un choix différent à un stade antérieur.

La formation et la certification des enseignants exigent de l'attention

Les enseignants se plaignent souvent d'un manque de moyens et d'opportunités pour réfléchir sur leur pédagogie et améliorer leurs connaissances. Dans de nombreux pays, les enseignants du primaire viennent pour la plupart de filières non scientifiques et beaucoup n'ont suivi aucune formation professionnelle spécifique dans les S&T. Ce constat peut également s'appliquer à l'enseignement secondaire si les enseignants sont obligés d'enseigner des disciplines pour lesquelles ils n'ont pas de compétences.

La formation continue sur les innovations récentes fait souvent défaut et n'est pas axée sur les contenus théoriques des disciplines. De ce fait, et malgré une motivation souvent très grande pour leur travail, de nombreux enseignants de S&T peuvent avoir besoin d'actualiser leurs connaissances et risquent de ne pas être à l'aise avec les toutes dernières innovations scientifiques et technologiques qui sont celles qui intéressent le plus les élèves. Les professions scientifiques évoluent elles aussi à un rythme accéléré mais les enseignants pour la plupart n'ont pas accès à l'information sur les perspectives d'évolution professionnelle des étudiants de S&T et répugnent par conséquent à proposer des conseils d'orientation.

Le personnel enseignant des S&T est souvent recruté en fonction de ses compétences dans les disciplines qui lui sont propres et non dans la façon dont il les enseigne. Dans de nombreux pays, ce recrutement n'inclut aucune formation complémentaire sur la pédagogie pour ces disciplines. Ce problème se pose avec une acuité particulière dans le

supérieur où les enseignants sont d'ordinaire uniquement évalués en fonction de leurs performances en recherche, ce qui peut conduire à des taux élevés d'abandon des études.

Recommandations

Les gouvernements et institutions concernées devraient apporter les moyens nécessaires pour la formation des enseignants et l'organisation d'expériences pratiques, ainsi que récompenser les professeurs qui font l'effort d'actualiser leurs savoirs et savoir-faire, ou qui investissent du temps dans la communication des S&T. Une information particulière devrait également être apportée aux enseignants lors de leur formation initiale, afin de limiter la transmission de stéréotypes aux élèves, notamment aux filles et aux élèves appartenant à des minorités. L'enseignement bénéficierait aussi d'échanges d'information et de bonnes pratiques au sujet de l'enseignement des S&T entre enseignants des différents cycles, du primaire au supérieur.

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Introduction

Knowledge is already one of the main drivers of today's economic system. In the future those nations, regions, and even local areas that succeed best will be those capable of capturing the benefits of scientific and technical innovations and transforming them into marketable goods and services in the face of global competition. The education system is of course vital to this process, training the scientists, engineers and technicians who constitute the "human capital" of an increasingly fast changing, knowledge intensive economy. But an understanding of science and technology is necessary not only for those whose livelihood depends on it directly, but also for any citizen who wishes to make informed choices about issues ranging from stem cell research to global warming to genetically modified organisms to teaching the theory of evolution in schools. And new issues are bound to emerge in the years to come.

One might expect then that the problem facing governments would be how to promote interest in the other disciplines, given the importance of science and technology, and the opportunities that knowledge of them offers. However, a number of countries have expressed the fear that student interest in S&T is declining, even as demand for S&T graduates grows. The Global Science Forum was asked to investigate whether this decline was really happening, and to analyse the reasons for students' choice of study and career.

Data were collected from 19 countries in order to assess the evolution of student enrolment in S&T. It was decided to study the number of students choosing S&T disciplines at each level from high school ("secondary education") to university or other higher education institutions ("tertiary education"). Since the available international data did not cover choices made at secondary level nor when first entering tertiary education, a special data collection exercise was conducted with the help of the participating countries.

The statistical data cover the life sciences, mathematics and statistics, the physical sciences, computing sciences, and engineering for four categories: secondary level/high school diploma; entrants in tertiary education; tertiary graduates; and doctorates. When available, data were also analysed by gender and by national/foreign origin. The time span is 1993-2003 for most data categories, and 1985-2003 for some others. Academic and vocational studies data were aggregated.

Rationale for collecting new sets of data

For some aspects such as the general level of educational attainment of national populations, comprehensive sets of data exist already, and can be found in *Education at a Glance*, published each year by the OECD. Where possible, these data are used here. However, limitations of the current international statistical system mean that a specific collection of data is needed to study specific issues related to interest, enrolment and graduation in science, technology, engineering and mathematics (S&T) studies.

First, to conduct the trend analysis, the data must be established on a regular timeframe. There are not many relevant international sets of data presenting such time series. The Programme for International Student Assessment (PISA), of which the main focus is the 15-year-old students' performance in mathematics, reading and science, provided in 2003 an analysis of the motivation of these 15-year-old students in mathematics and in the 2006 cycle, such an analysis on interest for sciences. PISA cycles are based on a 3-year framework and the focus of each session rotates. Since the 2009 series will focus on reading again, the first possible comparison of trends will occur in 2012 for maths and 2015 for sciences. In addition, it can be considered that a "hard fact" study should be grounded on actual acts and choices rather than on a declared interest.

Second, relevant data are generally available only at the tertiary level. As interest may change over time and throughout the different stages of education, it is interesting to follow the numbers of students at different levels from the end of secondary education to tertiary graduation. Moreover, from the point of view of future trends, the number of students at the early stages of the choice process is of particular interest.

Third, available data by field of study are rather limited in detail and time span. The 1997 revision of the International Standard Classification of Education (ISCED, described in detail below) introduced a break in time series by changing the definitions of educational levels and disciplines, preventing analysis of trends over time. Thus, a specific collection of these details at the national level was considered necessary.

The specificities of our data collection

Series and period

The data cover the period 1985-2003 and include four different series:

1. Upper secondary graduates.
2. New entrants in tertiary education.
3. Graduates from tertiary education (aggregate numbers for ISCED levels 5B, 5A and 6, which means all levels of tertiary studies including doctorates).
4. Doctoral graduates separately.

Scope

For each one of these series, we collected data on the total number of students of the considered level and those with an S&T orientation.

In S&T, we chose to include life sciences, mathematics and statistics, physical sciences, computing sciences and engineering, with detail by discipline.

We collected also the split between genders and nationality status, with two categories, citizens and foreigners.

The 19 countries for which data have been provided are: Australia, Belgium (Flanders + Wallonia), Canada, Denmark, Finland, France, Germany, Italy, Israel, Japan, Korea, Netherlands, Norway, Poland, Portugal, Sweden, Turkey, United Kingdom, United States.

Specificities and limitations

Few countries provided the whole set of data requested for various reasons, most of them being linked to changes in classification or unavailability of the split between disciplines. This was particularly the case for upper secondary graduates.

Moreover, because of the revision of the ISCED classification in 1997, we had to rely on data provided by the countries and were thus dependant on their internal definitions.

An analysis focussed on trends rather than absolute levels

In a context where the international comparability of data faces such limits, it is reasonable to avoid comparison of absolute numbers and focus on trends. Therefore, many of the analyses focus on the *evolution* of the numbers of students enrolled in S&T disciplines and not on the level of these numbers.

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Chapter 1

Quantitative Analysis: Is There a Real Decline?

Absolute numbers of science and technology (S&T) students have been rising in line with access to higher education. However, their relative share has been falling in tertiary education and upper secondary levels in several OECD countries. Coupled with unfavourable demographics and a stabilisation of the number of students accessing tertiary education, several OECD countries may see the absolute number of S&T students declining in future years. In other countries, a demographic recovery would mitigate this trend. Aggregate numbers hide important differences among disciplines. For physical sciences and mathematics, the absolute number of students often shows a decline. Life sciences' share has mostly remained stable due primarily to an increasing number of female students. Engineering benefits from the perception that job prospects are good and shows a stable or positive trend. The number of computer science students has increased dramatically, perhaps reflecting a shift away from physics.

Introduction

Any discussion of how to encourage student' interest in S&T has to start by taking stock of the current situation regarding the status of S&T enrolments, the objective background to this status and how the situation has evolved. While it should be stressed that enrolment does not necessarily reflect interest in a particular field of study, governments are primarily concerned by the end-result and whether the number of young people trained in S&T matches the demand of society. This means looking at the demographic trends affecting the school-age and university-age populations, the educational choices and performance of people in these age groups, and the trends in S&T graduates. Since children at primary school and early secondary school do not usually have any choice regarding whether to study science or not, the analysis here concerns students aged 15 upwards. The analyses focus on trends rather than on absolute numbers, since numerous differences between countries in definitions often prevent useful conclusions to be drawn from raw numbers.

Overall trends

1.1.1. *Demographic trends*

Educational attainment is rising throughout the OECD area, both in terms of numbers of students enrolled at various levels and those going on to attain higher levels of qualification. In the years to come however, the population most concerned by education (those aged 5-24) is expected to decline both in numbers and as a share of the overall population. According to the UN medium variant population projection, for the more developed countries as a whole, the 5-14 age group represented just over 15 per cent of the population in 1980 and is projected to decline to 11 per cent by 2010. Over the same period, the population aged 16-24 is expected to decline from 16.6 per cent of the total population to 11.7 per cent.

Most countries studied experienced a significant decline in their young population (15-19 year-olds and 20-24 year-olds) with only a few exceptions. This decrease has been continuous over the period in the EU15 but more recent, in the early 1990s, in Japan. There are exceptions, however, including the US (since the early 1990s), Korea or Austria for instance. This negative trend has reversed in some countries in very recent years, for example the Netherlands, Norway, Portugal, Sweden and the United Kingdom.

1.1.2. *Enrolment rates*

The decline in the numbers of young people has coincided with efforts to expand access to higher level education, so instead of the decline that might be expected when considering only cohort size, there was in fact an increase in enrolment rates, leading to an overall increase in student numbers, as described in more detail below. In the Netherlands, for example, the 20-24 year-old population decreased by nearly 25% over 1985-2001, but the number of graduates increased by 25%. In Denmark, although the number of 20-24 year-olds dropped by more than 20%, the number of graduates increased by 40%.

Figure 1.1. **Population aged 15-19 years**
(in thousands)

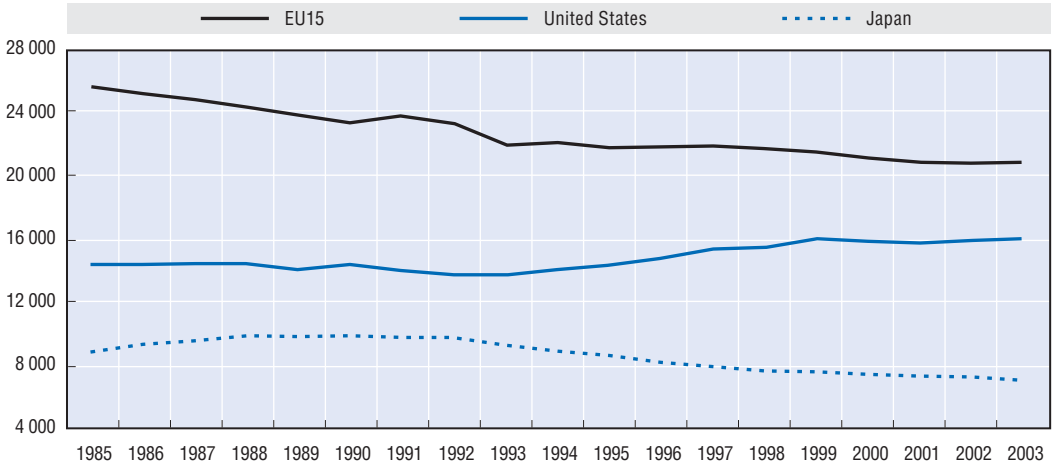
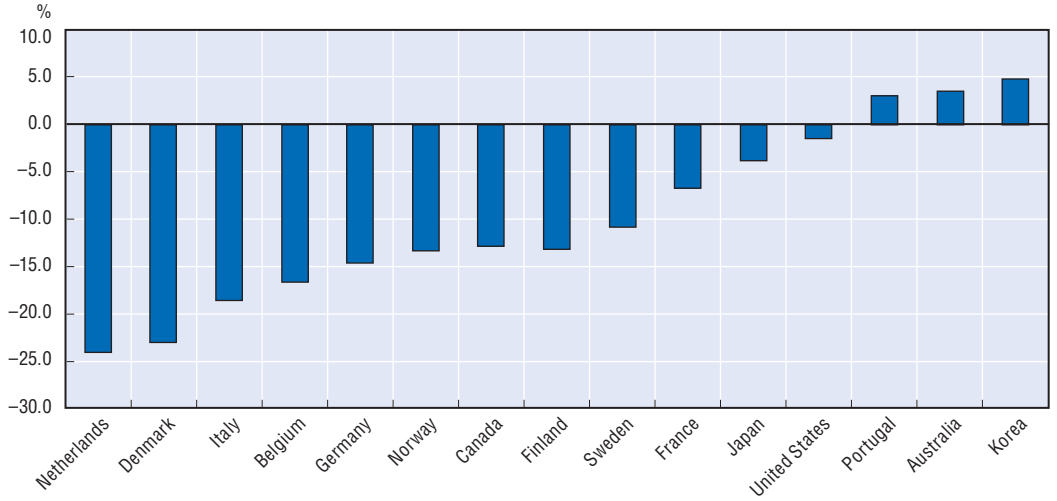


Figure 1.2. **Population aged 20-24 years**
Per cent change 1985-2003



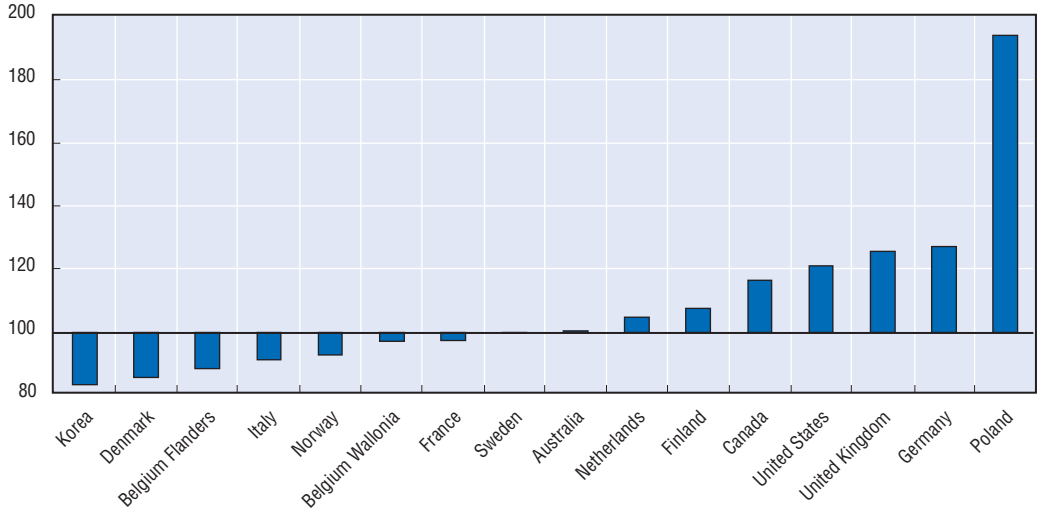
Secondary education

The decision to pursue S&T studies is often made during the second part of secondary education, and of course depends on completing this stage successfully. Enrolment in upper secondary education has been expanding in all countries, and graduation from upper secondary education is becoming the norm in most OECD countries. Since 1995, the upper secondary graduation rate has increased by 7 percentage points on average across OECD countries with comparable data. The highest growth occurred in Greece, Norway and Sweden, whereas in Germany, Japan, New Zealand, the Slovak Republic, Switzerland and the United States the level has remained stable over the last ten years. In 19 out of 21 OECD countries and in 2 other economies for which comparable data are available, upper secondary graduation rates now exceed 70%. In Finland, Germany, Greece, Ireland, Japan, Korea and Norway graduation rates are at least 90%.

Thus, declining demographic trends have been counterbalanced to some extent by better access to upper secondary education. As a result of these opposing trends, the *number* of upper secondary graduates increased over the period in most countries analysed.

Figure 1.3. **Trends in the number of upper secondary graduates**

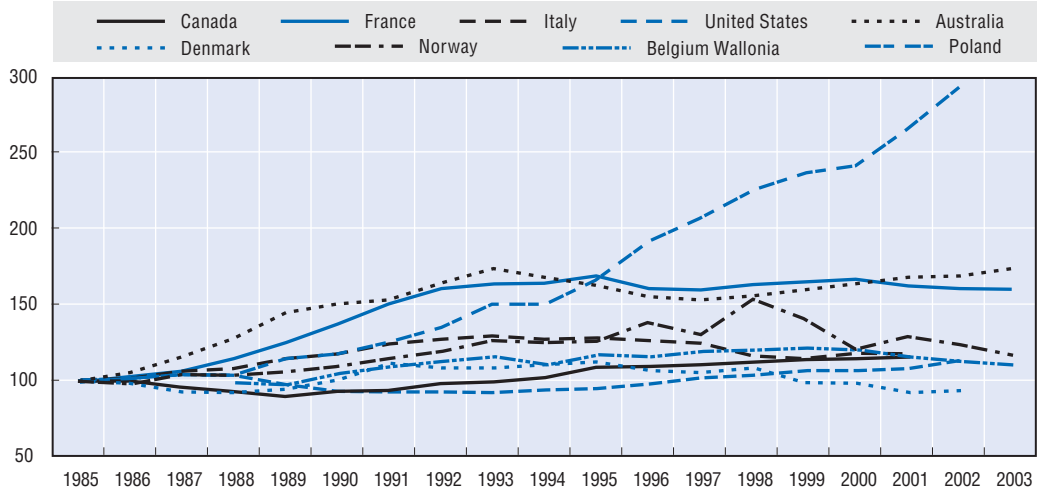
Index 1985 or first year = 100



This increase in the number of upper secondary graduates started in many countries in the 1970s and was still noticeable in the first half of the period from 1985 to 2003. Starting in the mid-1990s however, the numbers start to stabilise or even decline in some countries. Global trends can, in addition mask, important variations within countries. For instance in France, the number of upper secondary graduates increased by 70% from 1985 and 1995, but slightly decreased afterwards, while in Korea, a succession of ups and downs resulted in an overall reduction of 22% between 1991 and 2003.

Figure 1.4. **Upper secondary graduates 1985-2003**

Index 1985 = 100



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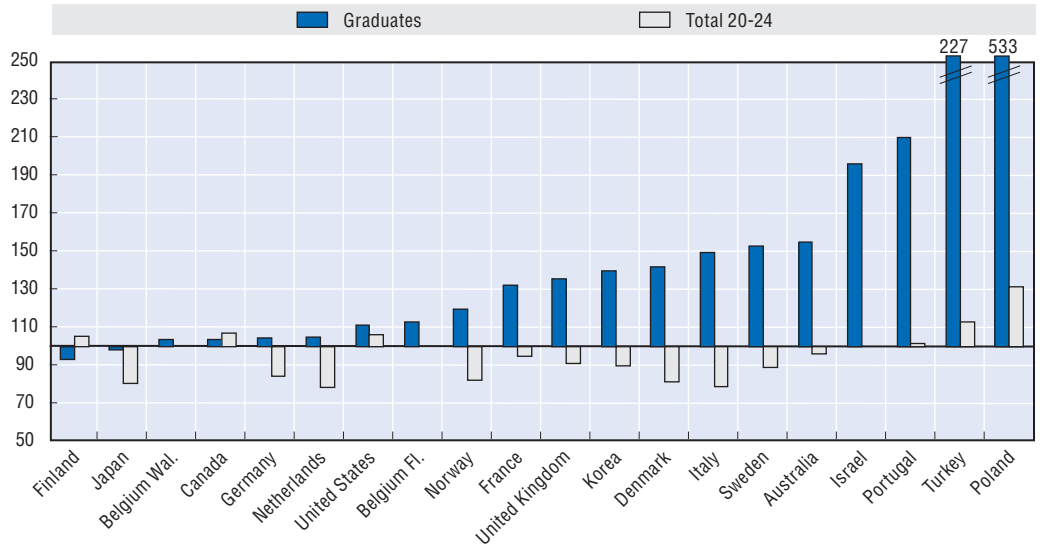
Tertiary education

Despite the unfavourable demographical context, the number of tertiary graduates has increased strongly over the last 15 years, as a result of increasing access to tertiary education.

Figure 1.5. **Tertiary enrolment**

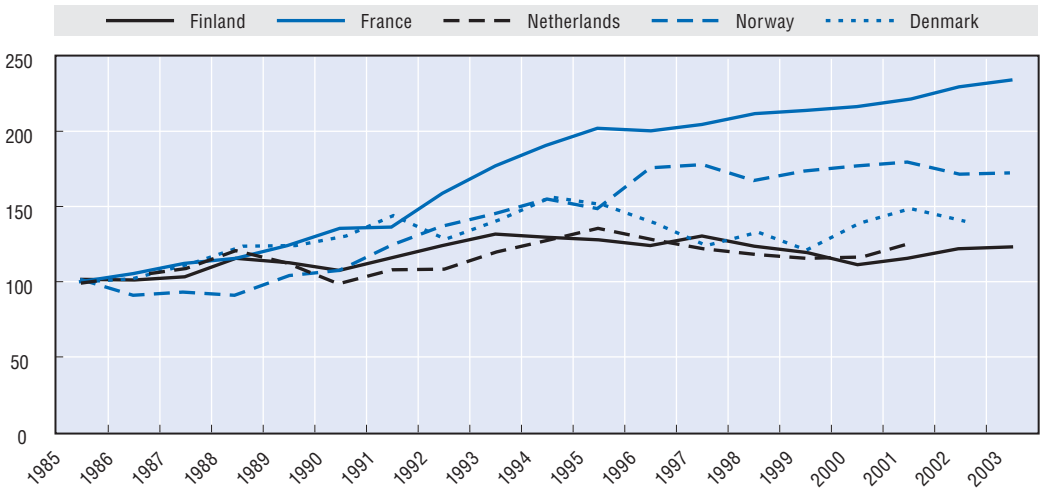
Index of change between 1993 or first year and 2003 or last year (1993 = 100)



In some countries however, data show a lesser increase or even a stabilisation of the number of graduates towards the end of the period, mainly after 1995. This is the case for Finland, France, the Netherlands, Norway, and Denmark.

Figure 1.6. **Number of graduates**

Index 1985 = 100



In rare cases, as for Japan, declining cohorts of young people have led to an overall decrease of graduate numbers. However, it must be remembered that in Japan the number of places available in higher education is regulated by the state and thus the number of graduates does not reflect directly the candidacies and enrolments of potential students.

Advanced research qualification rates

Across the 27 OECD countries with comparable data, an average of 1.4% of the population obtained an advanced research qualification (such as a PhD) in 2005. The percentages range from 0.1 per cent in Mexico and Chile to more than 2 per cent in Germany, Portugal, Sweden and Switzerland.

Quantitative trends in student choice for S&T studies

As mentioned elsewhere, a new data-gathering exercise was needed to overcome the limitations of the current statistics, notably concerning pre-tertiary levels. The revision of the ISCED (International Standard Classification of Education) in 1997 complicated matters by changing the definitions of educational levels and disciplines and thereby introducing a discontinuity in data series.

In many countries, high school systems follow a comprehensive scheme where students can choose their subjects on an optional basis. In addition, in several countries, secondary education is not uniform at the national level, being the responsibility of states or provinces. Thus, defining what is "choosing S&T" at this level for international comparison is methodologically difficult. Also, countries were requested to provide data on students receiving an upper-secondary degree with high S&T content using the definitions that seemed most appropriate to them, as long as these are consistent from one year to another, to allow trends to be analysed in each country and compared between countries. This means that the taxonomy and therefore absolute numbers may not be consistent from one country to another. Also, in many countries, the distinction between specialties does not exist or is new.

The quantitative study thus encountered significant limitations and obstacles, largely because it relied on specific national data sets. Ideally, an optimal analysis of student numbers would be based on complete sets of homogeneous data, in which countries would apply identical (or very similar), definitions of diplomas, educational levels, student categorisations, etc. Moreover, these definitions would be stable over time. Since this is not the case, the analysis was often limited to comparisons of trends and ratios, rather than of absolute numbers.

Extrapolating student interest in specific disciplines from numbers of students in S&T studies must also be done with caution, as the relationships among numbers, choices, and the degree of interest in S&T studies are complex and indirect.

1.2.1. Analysis of early choices: trends at secondary level

Bearing in mind these precautions, the data presented below for secondary education reveal a mixed pattern, with three countries showing a steady increase over 1997-2003 (Finland, Germany, Israel) and the rest a decline, but with fluctuations, except for Flanders, where decline is steady. The most spectacular decline over 1997-2003 is for Korea, with the level in 2003 just over 70% of that in 1997. The more drastic decline shown in Norway after 1999 is partially due to a change in definitions.

As the graph below shows, analysis over a longer period confirms the uneven nature of the trends, illustrating that significant changes can occur in a relatively short time, and that the direction of change can fluctuate even more rapidly. In France, for example, numbers rose from a baseline of 100 in 1985 to over 140 in 1993, before falling back to 120 in 2003, but with fluctuations between times. In Norway, numbers in 2003 were only about

Figure 1.7. **Upper secondary S&T graduates from 1997**

Evolution of the number of upper secondary graduates with an S&T orientation – Index 1997 = 100

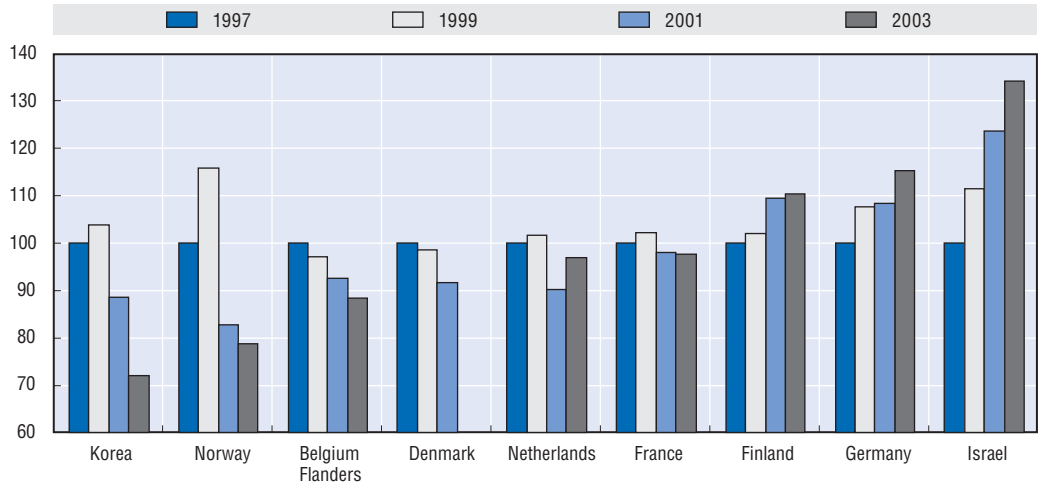
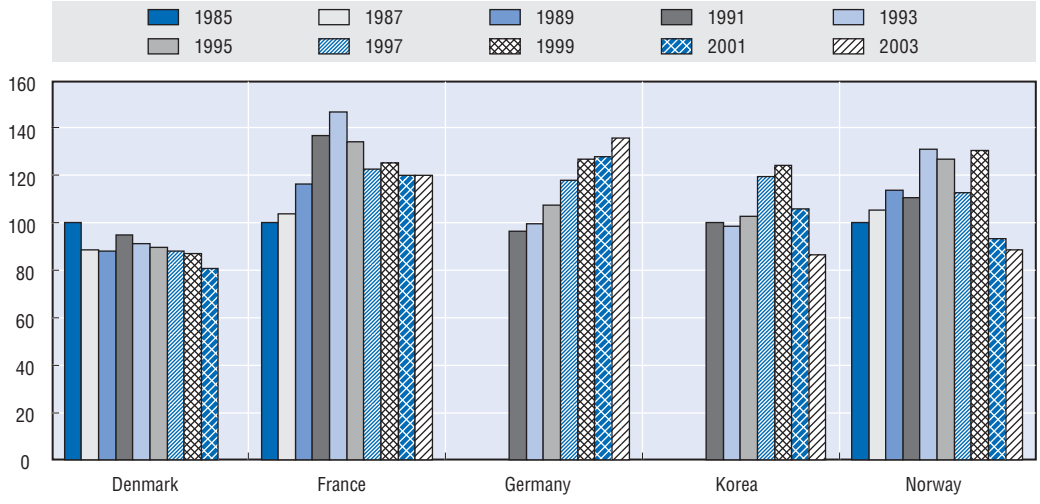


Figure 1.8. **Upper secondary S&T graduates from 1985**

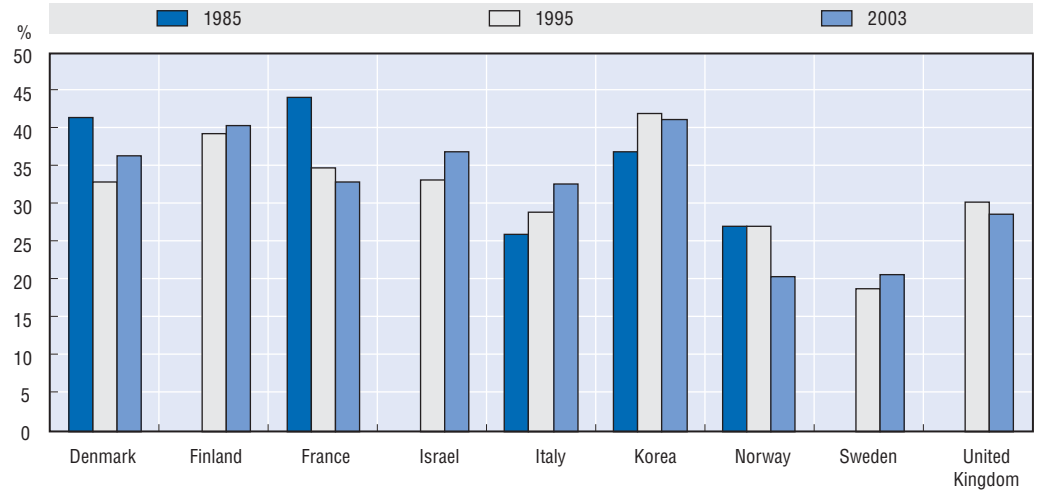
Evolution of the number of upper secondary graduates with an S&T orientation – Index 1985 = 100



90 per cent of those in 1985 after peaking at 130 per cent in two separate years and no increase or decrease lasting more than two years in a row.

Changes in absolute numbers may be due to demographic effects – more or fewer students choosing S&T may simply reflect an increase or decline in the number of students, rather than a growing or shrinking interest in these subjects. It is necessary, therefore, to look at how the relative shares of S&T have evolved over time. As shown in the figure below, national patterns once again vary, but do not mirror those shown when considering absolute numbers. For Finland, Israel, Italy, and Sweden, the percentage is higher in 2003 than in 1995, and in Denmark, following a decline over 1985-1995, the share had increased again by 2003. None of the percentage increases is as spectacular as the increase in numbers, suggesting that much of the increase may be due to a general expansion in student numbers rather than growing interest for S&T.

Figure 1.9. **Upper secondary S&T graduates from 1985-2003**



The data for Korea by percentage do not show the same dramatic decline as simple numbers would suggest, in fact the trend is now reversed, with an increase over 1985-2003, although the percentage for 2003 is slightly lower than in 1995. Norway's decline is maintained over both sets of data, but the amplitude is much less when percentages are considered.

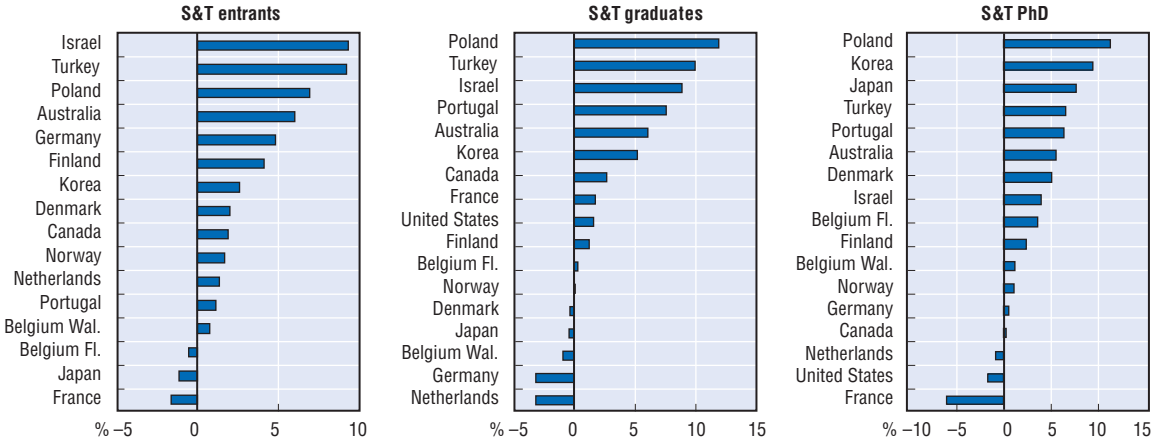
The strongest decrease occurred in France with the share of S&T upper secondary graduates falling from 44% at the beginning of the period to 33% at the end. This coincides with a strong increase in the overall number of upper secondary graduates (which grew 1.6 times) while the number of S&T graduates increased very moderately. This could indicate that the significant expansion of upper secondary education during the period included large numbers of students who do not show the same interest for S&T as previous cohorts. It could also indicate that S&T subjects tend to be perceived as elitist, and that their proportion of students rises with the degree of selectivity of the educational level, *i.e.* a system which places few restrictions on access to upper secondary education and the choice of subject will have a lower share of students taking S&T than one where access is restricted to the most academically able students.

1.2.2. General trends at tertiary levels S&T

The numbers of students choosing S&T on entering tertiary education rose slowly but steadily over 1993-2003, partly as a direct reflection of the expansion of education at this level, with a few exceptions. For instance, France showed the strongest increase between 1985-1993, but numbers declined from the mid-1990s onwards, perhaps because of the reform of the "baccalauréat" system which reduced the proportion of students in S&T in upper secondary level. Similarly, in Japan, numbers of entrants first increased strongly in the 1980s but started decreasing in the early 1990s, while in Germany a decrease in the early 1990s was followed by an increase.

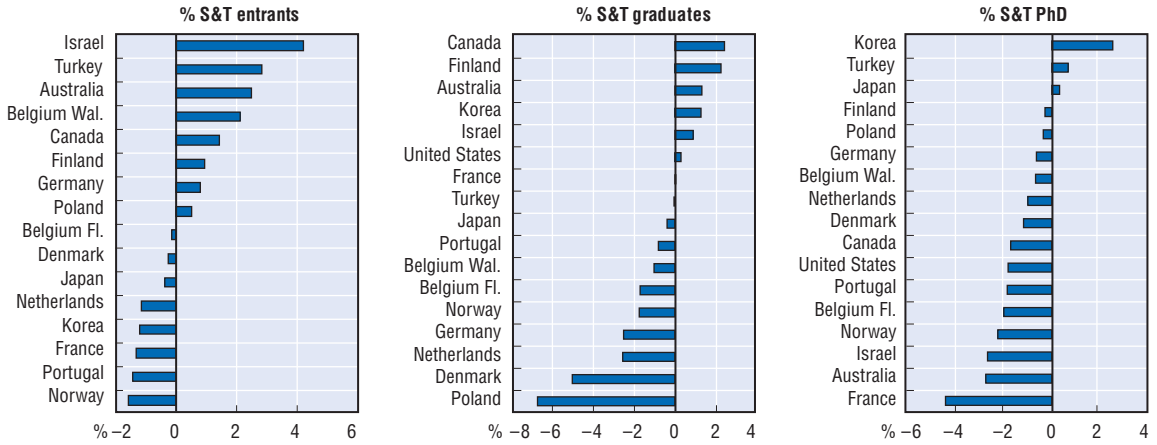
The percentage of graduates in S&T disciplines declined in 10 countries out of 17 over 1993-2003, and the trends are even more negative at doctorate level, with all but three countries showing negative trends. After a period of growing numbers of PhDs, trends started to decline in the late 1990s for the United States, France, Canada and Germany. The number of S&T doctorates has declined by 25% since 1996 in France, 15% since 2000 in Germany and 15% between 1996 and 2001 in the US (see figure).

Figure 1.10. **Number of S&T students – 1993-2003 average annual change**



However, as the data for secondary level indicated, trends in absolute numbers tell only part of the story. When the share of students choosing S&T studies is examined, the changes are less marked than those for numbers of students, generally being less than 3% one way or the other, except for Israel, with an increase of just over 4% in S&T entrants. Fewer countries showed an increase in percentage than in numbers, and in fact as a percentage of all students, S&T students declined in half the countries considered over 1993-2003. The biggest declines (over 2%) were in the Netherlands, Korea, France, Portugal and Norway. Apart from Israel, Turkey, Australia and Wallonia showed the biggest increases (over 2%).

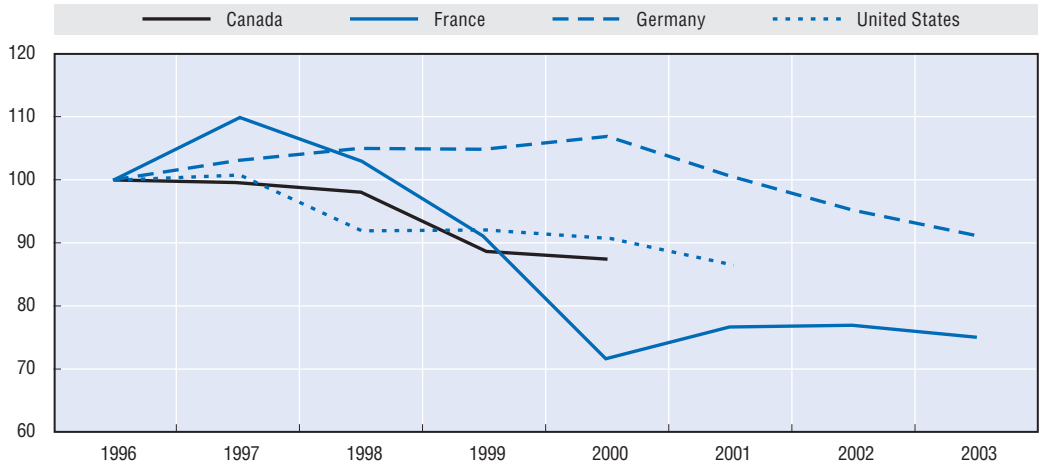
Figure 1.11. **Percentage of S&T students 1993-2003, average annual change**



Looking at the percentages of graduates and doctorates over a ten-year period reveals a downward trend that is mostly hidden when simple numbers are taken into account: only six countries show an increase in the percentage of S&T graduates, and at PhD level the decline is even more apparent, with only Korea, Turkey and Japan showing an increase, and for the latter two this increase is less than 1% over the period.

Figure 1.12. **S&T doctorates**

Index 1996 = 100

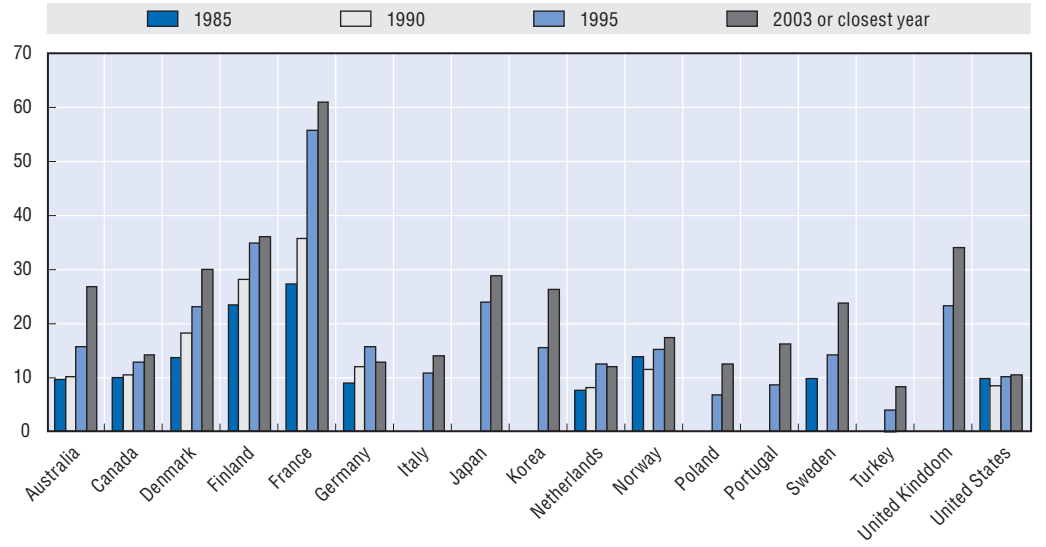


For a more recent period, even absolute numbers show a decline for some countries that benefited from an increase overall for 1993-2003. The graph above, starting in 1996, provides a stark illustration of this for Canada and Germany, which both showed a slight increase in numbers over 1993-2003, and confirms the declines registered by France and the United States.

The number of S&T graduates relative to population at the age of graduation

The number of S&T graduates per thousand 20-24 year-olds has generally increased over the period, mainly due to the increase of the share of each generation that reaches graduation. One of the most significant increases occurred in France, where the number of S&T graduates progressed from 27 per thousand 20-24 years-olds to 56 between 1985 and 1995. This is explained by the very large increase in the total number of graduates, even though the share of S&T graduates decreased from 31% to 27%. In the US, on the other

Figure 1.13. **S&T graduates per thousand 20-24 year-olds**



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hand, an upturn in the number of 20-24 year-olds and number of graduates after 1996 did not lead to a significant increase in the number of S&T graduates.

In Germany a significant decline in the 20-24 year-old population between 1993 and 1999 and a recovery after that are reflected in the number of graduates overall as well as in S&T. The link between demography and numbers of S&T graduates is not automatic, however. Despite declines in both the population of graduation age and the number of graduates, Japan did not experience a decline in S&T graduates. This can be explained by the fact the number of students in each discipline is regulated in Japan, and the demand constantly exceed the number of places available, so a decline in the potential overall number of candidates does not translate into a decline of graduates.

Conclusion

The expansion of higher and tertiary education over 1985-2003 resulted in an increase in the absolute numbers of S&T students, as well as in the number of S&T students relative to the 20-24 year-old age group. However, at the same time, the number of students choosing S&T declined as a proportion of all students in many countries, while the percentage of those graduating in S&T declined in the majority of countries and the percentage of those awarded a PhD declined practically everywhere.

These overall trends may hide marked differences between countries, disciplines and types of student, so the following section looks in more detail at what students are studying at higher level generally, and how the different S&T disciplines compare among themselves.

1.2.3. Detailed trends at tertiary level S&T

Governments and firms are aware that the shift towards a knowledge economy implies a general "upskilling" of the labour force, and an expansion of the numbers and share of workers graduating from tertiary education. For instance, for the EU to meet the goal of the 2000 Lisbon Agenda of making Europe "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion" by 2010, an extra 700 000 researchers in addition to those needed to replace the ones retiring may be required. And, as argued elsewhere in the present report, a knowledge-based society also needs people competent in S&T in many areas other than research, a point stressed in a 2003 EC Communication, recognising the need for highly trained knowledge workers in research-related functions such as marketing, communications and technology transfer (EC, 2003).

The supply of PhDs merits particular attention. While many workers in S&T areas do not possess PhD degrees, the supply of PhDs and their participation in the labour market is of special concern since they are the source of university teachers. Any policy effort to increase the quality and quantity of university graduates in science and engineering, or output from public research, will need to focus on the training of PhDs. Advances in scientific discovery and the productivity of the public research system rely mainly on PhD-trained personnel. Even in industry – which in most countries employs fewer PhDs than academia – the PhD is of particular relevance, especially in sectors high up the technological value chain whose research problems are close to those in basic research (*e.g.* the life sciences, nanotechnology, computing).

Yet, at the same time as the growing need for S&T graduates is recognised, trends in student choices show some worrying features, both in absolute numbers and in shares.

Social sciences, business, and law are the most popular studies in most countries, except Ireland where science is the main field; Finland, Germany, and the Slovak republic where it is engineering; and Denmark where health and welfare is the most popular (OECD, *Education at a Glance, 2007*).

Among the countries for which data is available, social sciences, business, and law make up 29% of the population educated to ISCED 5A and 6 level, education 15%, engineering 14%, art and humanities 13%, and science 11%. The leading position of social sciences, business, and law is due to increases in their share that have occurred recently. This generational shift in preferences can be seen by comparing the number of individuals aged groups 25- to 34-year-olds with ISCED level 5A and 30- to 39-year-olds with ISCED level 6 to those aged 55-to-64-year-olds with ISCED 5A and 6 level of education. (The 30-39 group is included because graduation at ISCED level 6 usually comes at a later age than level 5.)

The comparison shows that social sciences, business and law attracted three and half times as many young people with degrees in this field than in the older age group, and more than four times as many in France, Ireland, Italy, Portugal and Spain. This change is partly a mechanical effect due to increasing enrolments in tertiary education and increases in attainment levels in general, but it is also reflection of the fact these disciplines are becoming increasingly attractive to younger generations.

This raises concerns that at some point in the future, there will be a gap between the economy's demand for S&T graduates and the supply coming from the education system. This is not the case at present in the OECD countries, with three times as many people in the younger generations graduating than in the older generation (although it is likely to become a serious concern in education sciences in the near future). However, it is worth recalling *a)* that this increase is partly a mechanical effect of the increase in numbers in tertiary education and so may be expected to level off; *b)* that other disciplines are becoming increasingly popular among young people and the share of science is likely to suffer; *c)* there are wide differences among the various scientific disciplines; and *d)* the replacement rate of older generations may not be high enough given the shift of the economy towards more knowledge intensity, which could mean that the demand for scientific personnel grows faster than supply. These points will be discussed in more detail below.

Differences within S&T disciplines

Mathematics and physical sciences show a decline, while life sciences generally present positive trends. The situation is more varied for engineering, which in most countries accounts for a significant share (between 40% and 60%) of the overall number of S&T students, especially at the new entrants and graduates level. Variations in disciplines with smaller numbers of students may be hidden by any variation in the number of engineers, so it is particularly important to consider detailed data, broken down by discipline.

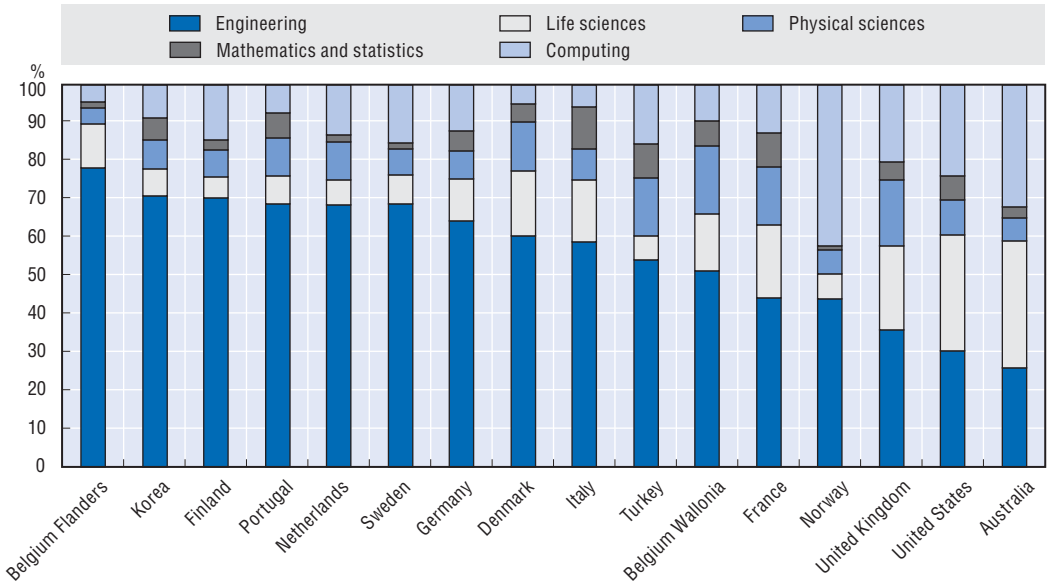
The national trends in the numbers of engineering graduates cover a large range of situations:

- Sharp increase for Turkey (+110% between 1994 and 2003), Portugal (+98% over the same period) and Korea (+87%).
- Milder but significant increase for France (+26% between 1994 and 2003) and Australia (+25% between 1994 and 2000).
- Flat trends for the UK, Finland and the US.

- Negative trends for a number of other countries: Norway (–40% between 1994 and 2003), Denmark (–20% between 1994 and 2002), Germany (–20% between 1994 and 2003) and the Netherlands (–6% between 1994 and 2001).

Figure 1.14. **S&T in higher education graduates**

Breakdown of S&T disciplines, 2003 or latest year available



Grouping science, technology engineering and mathematics can give an over-optimistic impression of enrolments and future supply of skilled personnel within the different fields. In a number of countries, enrolments in mathematics and physical sciences have declined. For example, in France, the number of graduates declined by 36% between 1994 and 2003 in physics and 6% in mathematics. In Germany, they declined by

Figure 1.15. **Mathematics and statistics graduates**

Index 1994 = 100

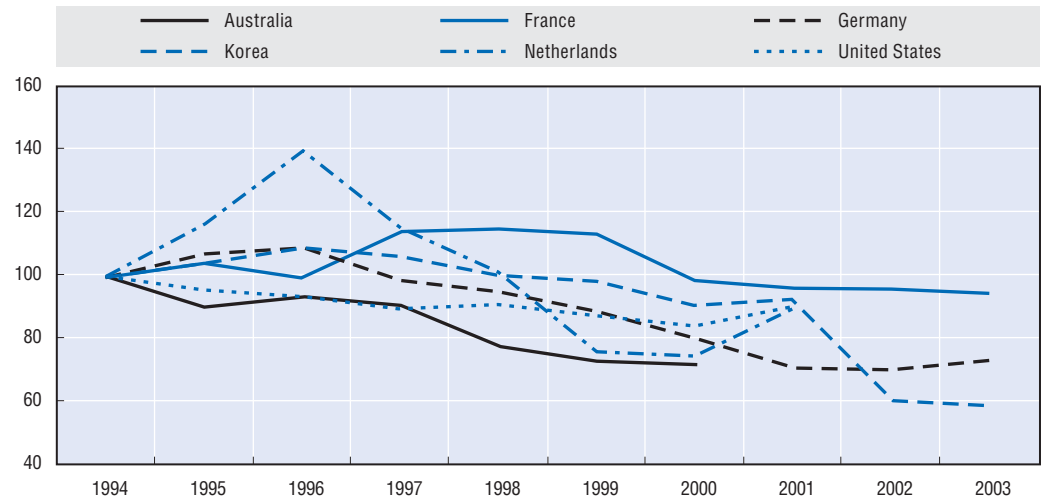


Figure 1.16. **Physical science graduates**

Index 100: 1994

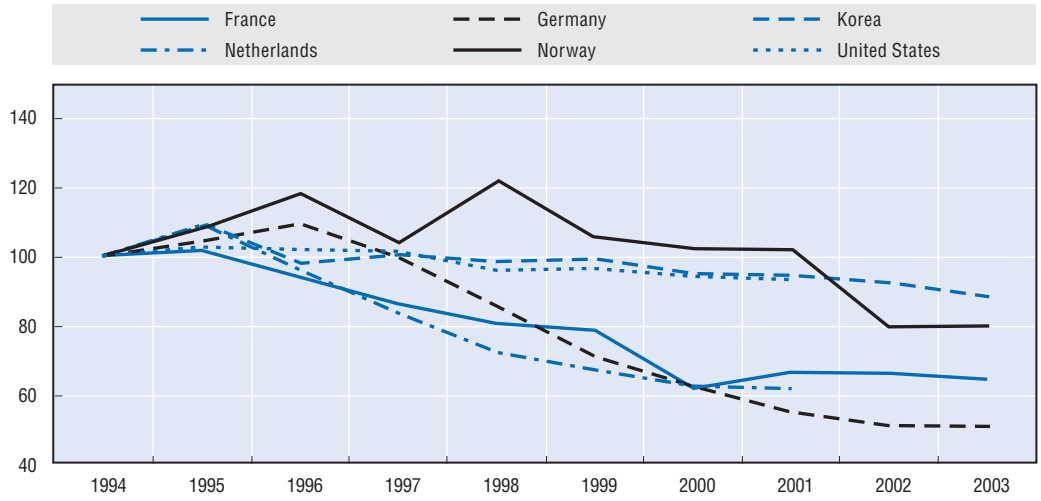
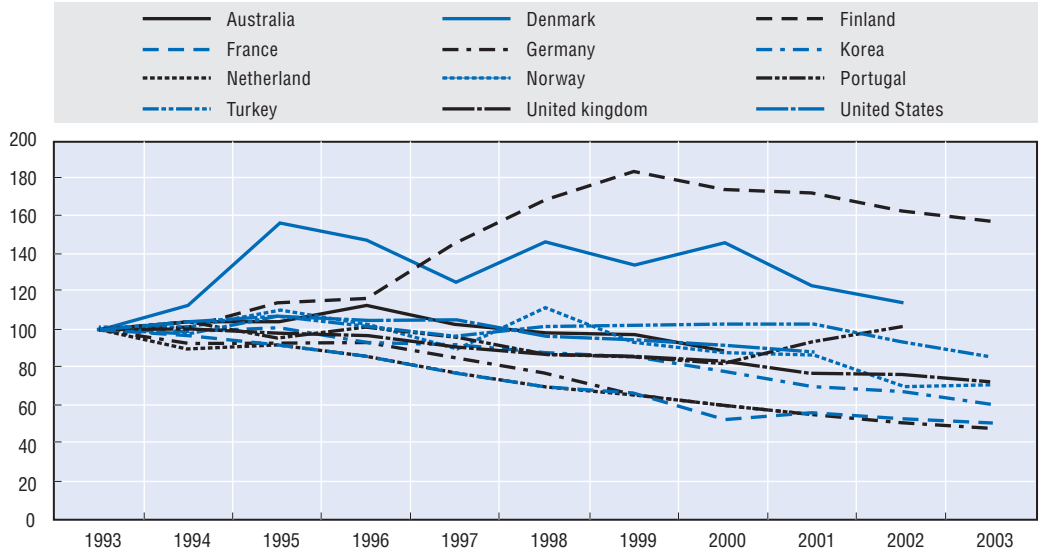


Figure 1.17. **Share of physical science graduates**

Index 100: 1993



50% between 1994 and 2003 in physics and 27% in mathematics. In the USA the decline was 7% in physics and 10% in mathematics between 1994 and 2001. The situation is even more dramatic when the share of students in mathematics or physical sciences is observed. Portugal, Sweden, Finland, Turkey and the United Kingdom have had more positive trends.

Apart from engineering, the high numbers of S&T graduates can be largely attributed to life sciences and, increasingly, to computing. Life sciences have retained significant levels of enrolment in most countries and even increased in some, but have also started to decline in some countries. Computer science has shown growth in every country surveyed, sometimes spectacular as in Korea (180% over 1994-2003) but growth rates are now levelling off, both as regards absolute numbers and as a share of total graduates.

Figure 1.18. **Share of life science graduates**

Index 1993 = 100

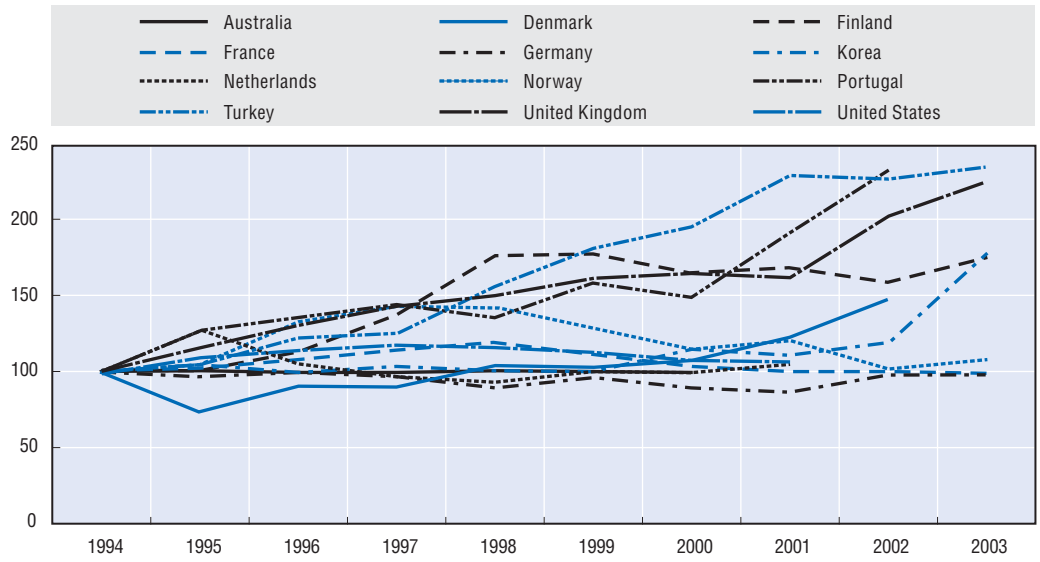
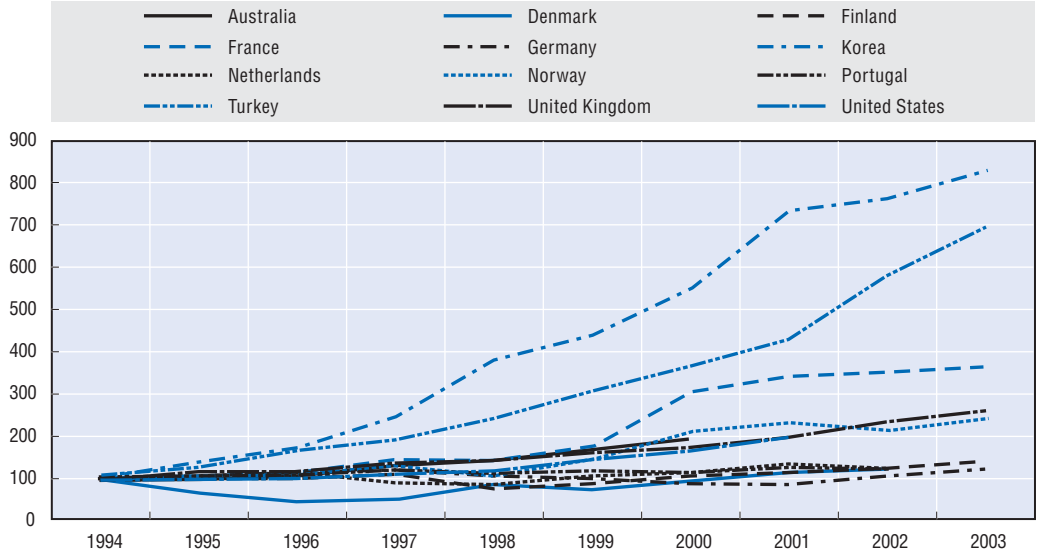


Figure 1.19. **Share of computing graduates**

Index 1993 = 100



Gender differences in S&T

The number of female graduates in S&T has increased strongly over the period in most countries, reflecting the strong increase in the overall number of female students, and the rate of increase has been stronger than for males in all countries except France and Italy. It is worth noting that the absolute number of male graduates in S&T has actually decreased in certain countries (Belgium Wallonia, Germany, Japan, the Netherlands and the United States).

Still, in most countries, the share of females in S&T disciplines is far below 50%, and is generally between 20% and 30%, with a few countries showing more than 35% (US, Portugal, Canada for new entrants and graduates) or under 20% (Japan, the Netherlands).

Moreover, the proportion of females choosing to study S&T is low in most countries and significantly lower than it is for males, and in 10 countries out of 15, this proportion decreased between 1985 and 2003.

Figure 1.20. **Female S&T graduates**

Index 1995 = 100

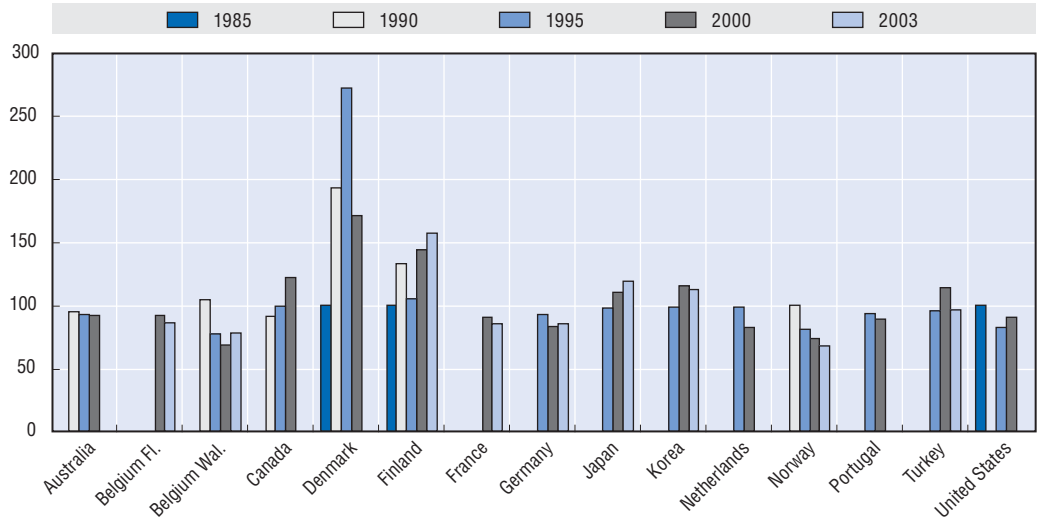
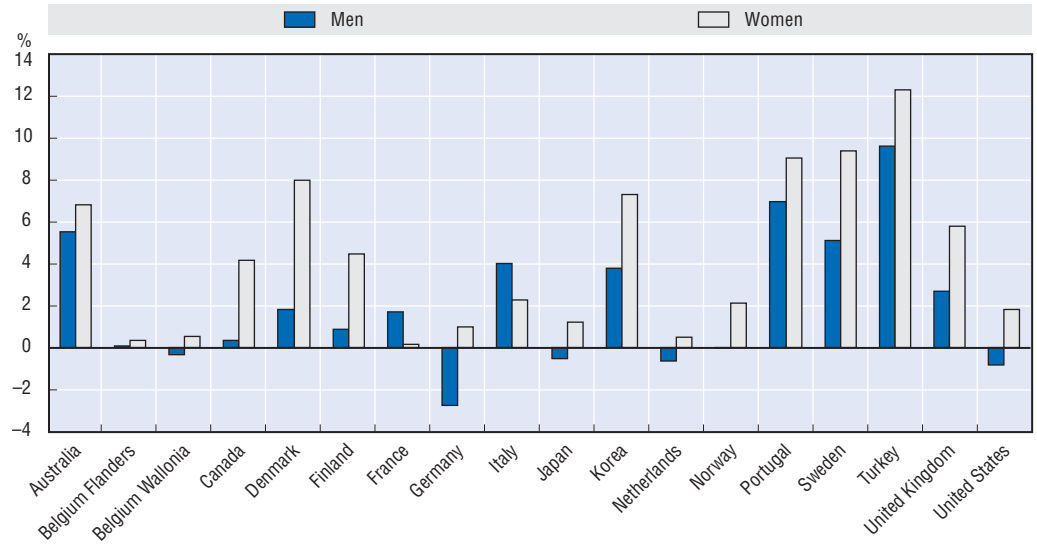


Figure 1.21. **Growth in S&T tertiary graduates**

Average annual growth rate – 1985-2003 (or closest available years)



Evolution of the proportion of women choosing S&T as a field of study

Women graduates are more numerous than men in the life sciences for all countries, but in most countries constitute less than 25% of computing and engineering students. It is worth mentioning that the percentage of female students is quite consistent within each discipline across countries (*e.g.* above 50% for life sciences), but the trends differ strongly within each discipline. For example, the percentage of female graduates in computing and engineering is generally somewhere between 10% and 30%, but in 1993-2003, this average declined by over 3%

Figure 1.22. **Female S&T graduates**

2003 or latest year available

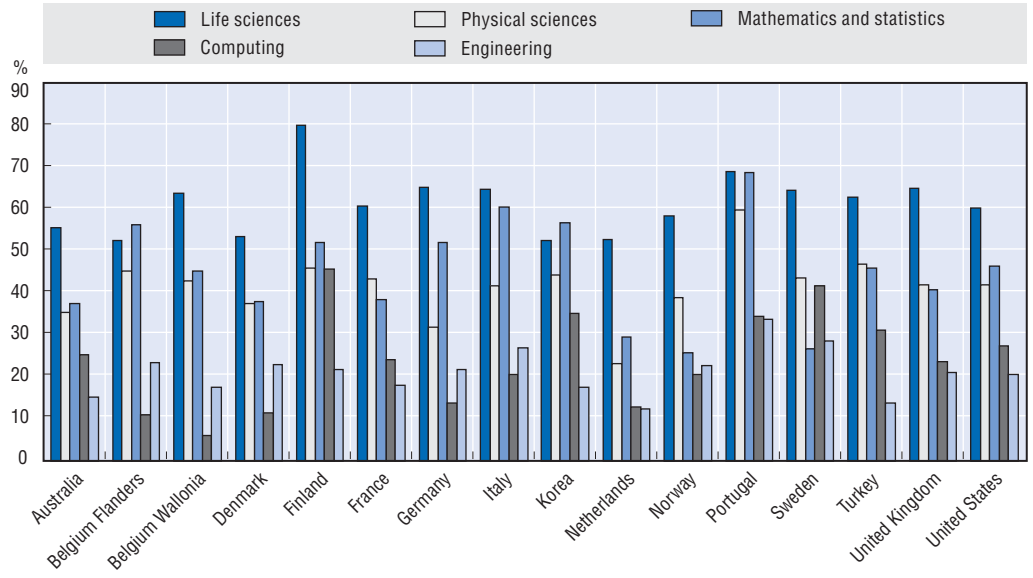
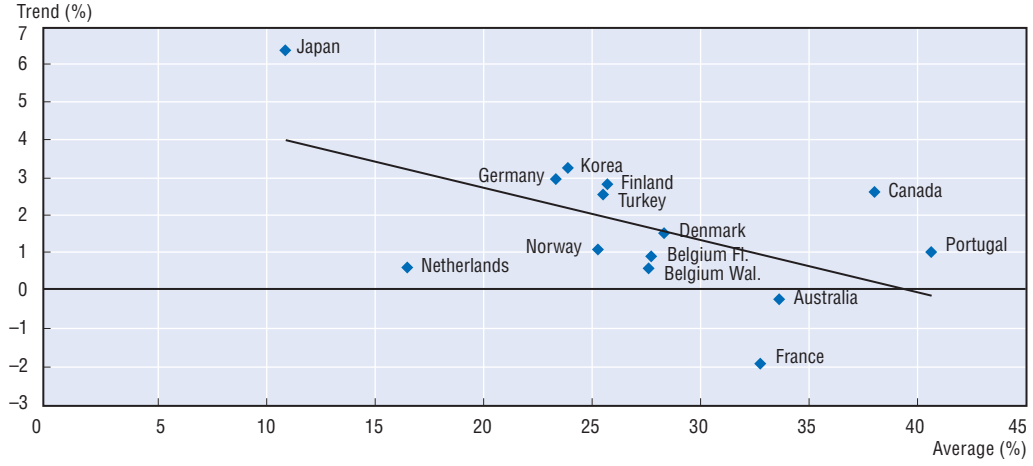


Figure 1.23. **Female S&T graduate trends**

1993-2003 trends *vs.* average



in France and increased by 6% in Turkey, with the other countries showing values somewhere between no change and an increase of 6%. The ratio increased most in countries where the base rate was low, *i.e.* where there was the most room for improvement, but the increase of female student ratio begins to tail off when approaching a 40% share. The same result is found for doctorates, leading some commentators to suggest that 40% represents a "glass ceiling" for women's share in S&T. (Gender-related issues are discussed in more detail later.)

Internationalisation of higher education

The number of students enrolled outside their country of citizenship has grown dramatically, from 0.61 million worldwide in 1975 to 2.73 million in 2005, and since 2000, the number of foreign tertiary students enrolled in the OECD area and worldwide increased by 48%, a 8.4% annual increase on average. Asian students form the largest group of

international students, with 49% of the total (47% in OECD countries, 57% in non-OECD countries). For educational institutes, internationalisation is intimately linked to the globalisation of science and research and the benefits of international knowledge networks. Foreign students can also compensate for a decline in enrolments by native students due to demographic trends or declining interest.

There are specific reasons to examine internationalisation as it affects science and technology. First, because the trend for national and foreign students is not necessarily the same. In most countries, at graduate level, the number of foreigners in S&T has increased more rapidly than that of nationals. In certain countries, in particular Australia and the United States, their participation in S&T is higher than that of national students. Thus, especially in countries in which the number of foreign students is significant, the trends for national students may be hidden by trends for foreign students. Second, in countries where the number of foreign students is high, policy makers may consider it important to assess the level of "autonomy" that the country has in its production of people with an S&T education.

Figure 1.24. **Annual S&T graduations**

Average growth rate

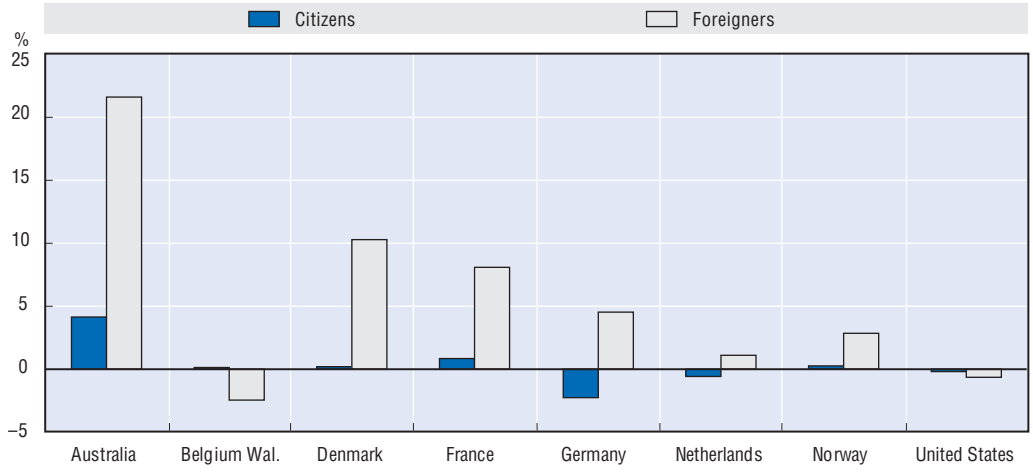
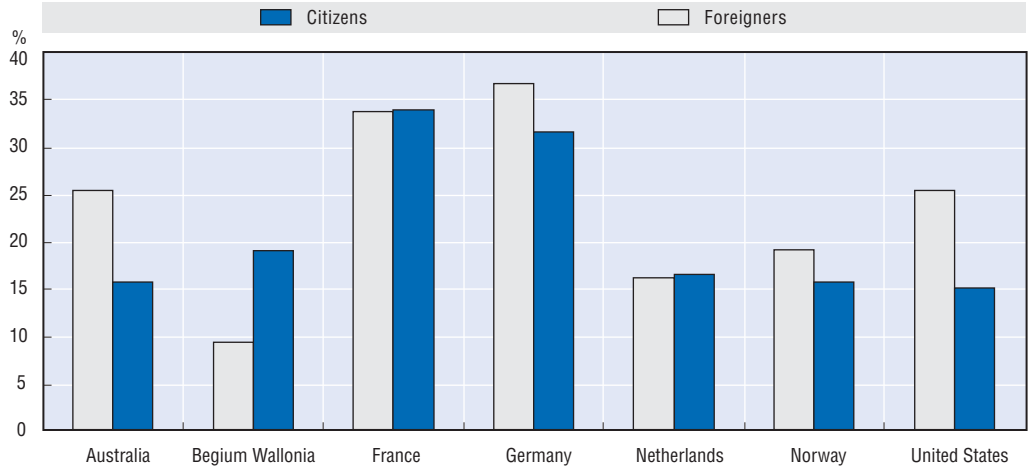


Figure 1.25. **Foreign S&T graduates**

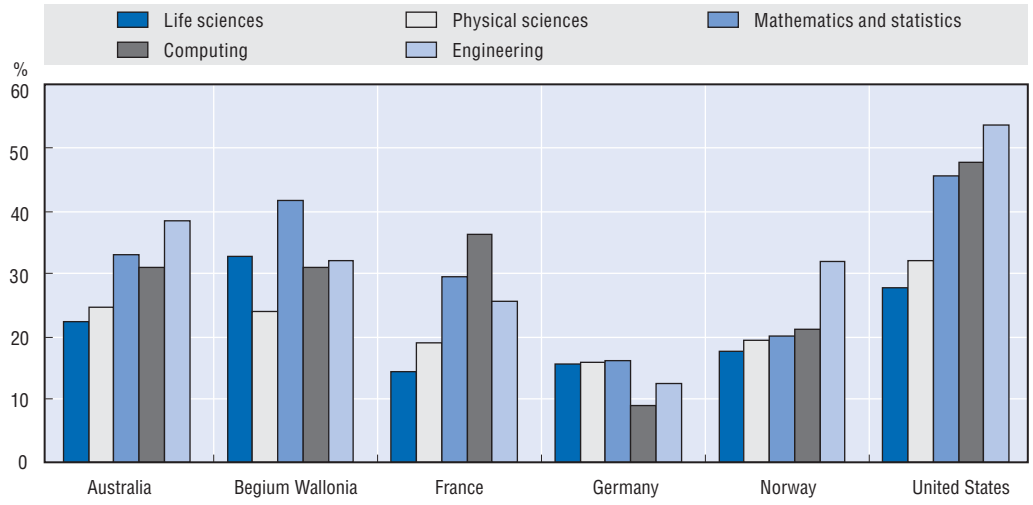
2003 or latest year available



Sciences at tertiary level generally attract about a sixth of international students in Australia (17.7%), Germany (17.4%), Switzerland (17.1%) and the United States (18.7%), but less than one in fifty in Japan (1.2%). However, the definition of sciences is important here. If agriculture, engineering, manufacturing and construction programmes are included, Finland receives the largest proportion of its international students in this case, at 42.4%. The proportion of international students enrolled in agriculture, sciences or engineering is also high in Australia (29.6%), Germany (38.1%), Hungary (32.6%), Sweden (36.8%), Switzerland (34.7%), the United Kingdom (30.6%) and the United States (34.6%).

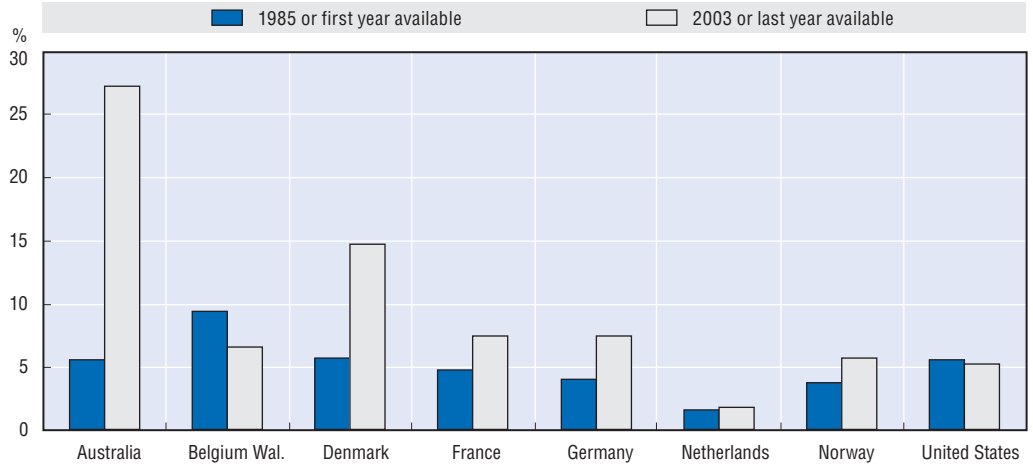
The distribution of foreign and international students by discipline varies widely from one country to another, and seems to be strongly influenced by the attraction of centres of excellence, with wide differences as the following table for doctorates illustrates.

Figure 1.26. **Foreign S&T doctorates by discipline**



In six countries out of the eight for which we have data, foreign graduates tend to represent a larger share of students than in the 1980s. In Australia, they even represent 27% of the S&T graduates at the end of the period covered.

Figure 1.27. **Foreign share of S&T graduates**



Conclusions

As a consequence of the growing enrolment rates in higher education, absolute numbers of students in S&T increased in most OECD countries over 1993-2003. This is true for each of the different stages of tertiary education (entrants, graduates, doctorates). In contrast, although data are not available for all countries, secondary level students with S&T orientation present uneven trends, especially in recent years. However, these data hide very important disparities between countries and, even more, between different fields of study.

While absolute numbers of S&T students have been rising over the period, the situation is very different when one considers the relative share of S&T students among the overall student population during the same period. This is true not only in tertiary education, but also for upper secondary graduates in many countries. This decline started around the mid-1990's and presents different patterns across countries.

Coupled with unfavourable demographics and a stabilisation of the number of students accessing tertiary education, several OECD countries can expect this general trend to affect the absolute number of S&T students in future years. In other countries, a demographic recovery would mitigate this trend.

Aggregate numbers hide important differences among disciplines. Engineering students account for 40% to 60% of S&T students in most countries, especially at the new entrant and graduate levels, and are characterised by a stable or positive enrolment trend over the past 10 years. The situation for physical sciences and mathematics is the opposite: a decline is often seen in the absolute number of students. In some countries, the proportion of students in such fields was halved between 1995 and 2003. On the other hand, the proportion of students in the life sciences has remained mostly stable, due primarily to an increasing number of female students. The number of computer science students increased dramatically but the rise has levelled off.

The number of female students in tertiary education has increased more rapidly than that of males, but the proportion of women choosing S&T studies is still lower than that of men. The share has often increased more clearly in countries that had the lowest proportion of female S&T students but trend analysis suggests that the proportion of female S&T graduates may hit a 40% "glass ceiling" even in countries most advanced in gender balance.

In most countries, women constitute less than 25% of computing and engineering students. In contrast, women are systematically more numerous than men in life sciences. The percentage of female students is fairly homogeneous within each discipline in the panel of countries analysed. However, trends in female student entrants or graduates within each field differ strongly between countries. The participation of women in S&T has thus improved in recent years but with a strong gender specialisation in the choice of disciplines.

Despite the many efforts conducted in the field of education statistics, the current statistical system does not always provide the breadth of information needed to analyse trends in students' choices at various levels. Databases would greatly benefit from the data on new entrants by field of study, information on foreign new entrants and graduates, and a distinction between graduations and graduates or first-time graduates and/or data on survival/drop out rates by field of education. Besides this, there is a need for better metadata information in order to help the interpretation of the data.

Most importantly, a quantitative study of the number of student choosing S&T disciplines does not necessarily reflect the actual evolution of students interested in S&T studies. Indeed, as S&T are among valued subjects, a decline in interest towards S&T studies may not directly translate into a decline in enrolment. Particularly in those education systems where a limited number of positions are available for each field in higher education institutions, enough candidates may still be available to fill the available positions in S&T, even if the overall number of candidates decreases. Thus, a decline in interest towards science studies may be more important than the one shown by enrolment or graduation data only. More qualitative analyses, such as on trends regarding best student's choices may also be required to provide a full picture of the situation.

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Chapter 2

Complexity of Contributing/Influencing Factors

Choice of study is determined by a range of objective and subjective, conscious and unconscious influences ranging from family background to salary expectations to experiences at school. Changes in the general social context, such as accelerating globalisation, also have an influence, e.g. *young people may choose broader types of curriculum with a wide range of disciplines to adapt to the job market. Female students are the most obvious resource for increasing science and technology (S&T) enrolments, along with young people from minority groups to some extent. Young female students suffer from stereotypes in relation to the expectations of parents, teachers, and society, despite doing at least as well as boys. Teaching tends to reflect the same stereotypes. Girls tend to undervalue their own performance, and their ability to pursue S&T. They also lack role models. In certain respects, this is also true for students belonging to some minorities.*

Introduction

Choice of study is determined by a range of factors combining objective and subjective, conscious and unconscious influences. These can range from family background to salary expectations to happy or unhappy experiences at school. Nonetheless, whatever the relative weight of each aspect in an individual's decision, the evolution of young people's interest in S&T studies has been mentioned in many different countries at the same time. These countries' cultures and educational systems vary considerably, hence it seems reasonable to look first for causes in the general international context and in phenomena that are common to these different countries. In other words, over the past decade, are there trends that cut across national differences that may help in understanding a possible decline in young people's interest for S&T studies?

Intensifying and accelerating globalisation has characterised every aspect of society, the economy and politics, and the world to which young people are exposed is more and more complex. The amount of information generated by this process has grown exponentially, so the desire to understand the underlying mechanisms of this rapidly

Box 2.1. **Selection of factors influencing student choice**

The factors having an impact on student choice to pursue or not S&T studies come from the contributions of the working group national experts, completed with a study of science education literature. The literature study includes surveys conducted among young people to collect their own analyses of the reasons why they are attracted to or repelled by S&T studies. Special care has been given to critically assess the value of what has been expressed by those surveyed as what is said and what is perceived are often only part of the underlying phenomenon. Other sources of information include large scale studies such as Eurobarometer, TIMSS, PISA, and ROSE.

Special attention has been paid to the earlier stages in the choice process and the building of interest in early youth. This decision was based on the fact that interest and taste are known to be intrinsic motivational factors with strong and persistent impact. It was also decided to pay particular attention to the groups of students that are generally not the main providers of future scientists such as female students, students with middle-range academic records, students from certain minorities and, in some countries, students from less-privileged economic backgrounds. These groups are considered as important resources in the design of a policy aimed at increasing S&T enrolment.

The contributing factors are grouped into five categories:

1. Image of S&T and S&T professionals.
2. Image of S&T careers.
3. S&T education and curricula.
4. Teacher training, qualification and development.
5. Gender and minorities.

changing world may have a direct impact on young people's choice in education. They may feel the need to choose broader types of curriculum with a wide range of disciplines to understand globalisation and the issues it raises. Science and technology may seem of little help in understanding most of the stories presented by the media, who tend (at best) to focus on politics and economics far more than science.

Changes in employment structures may have an effect too. In most developed countries, the share of parents working in industry is continuously decreasing. This may reduce the exposure of many children to practical applications of S&T and may impact the likelihood of many children becoming interested in S&T in their early years. Moreover, the poor situation of industrial sectors in many countries and the regular news about significant numbers of lay-offs, affecting many families may have acted as a deterrent to contemplating careers in science and technology.[1]

Recent evolution of the context

2.1.1. Societal evolution

Fluctuations in the job market

Unstable and unpredictable, the job market has gone through a series of rapid ups and downs over the last 20 years, and most jobs will undergo important transformations, as indeed will the way work is organised (OECD, 1994). With rising unemployment or precarious contracts, young people may be prone to operate a shift towards profession-oriented studies.

Social structuring

The family can influence younger children's interest in science in indirect ways. There is some evidence that children tend to attribute to mothers what is linked to the simple use of technical devices, whereas they attribute to fathers the more scientific and abstract aspects related to invention, development and maintenance of these devices (Cockburn, 1988). In many countries the increase in divorce rates has resulted in an increase of single-parent families, most of which are composed of the mother and children. These children are probably less exposed to the father's influence, but the effect of this on children's attitude to science requires more study. It could be that the aspects Cockburn claims are associated with the father suffer, but it could also be the case that they simply lose their gender specificity, and so actually help to encourage girls' interest.

In addition, the share of parents working in industry is continuously decreasing. This may reduce the exposure of many children to S&T practical applications and this may have an impact on the likelihood of children becoming interested in S&T in their early years. Moreover, the poor situation of industrial sectors in many countries and the regular news about significant numbers of lay-offs affecting many families may have acted as a deterrent to contemplating careers in science and technology.[2]

Expansion of tertiary education and diversification of possible studies

In many countries, the 1990s saw a strong increase in the part of the population acceding to tertiary education. The decline in the proportion of S&T students among the total of students may be explained as a mechanical result of the dramatic increase of tertiary education enrolments in many countries ("mix effect").

The continuous and significant increase in the number of tertiary education students has been accompanied by a modification of the composition of the students' backgrounds,[3] with an increasing number of women and students from less privileged social and economical backgrounds,[4] or minorities, and more often with average academic records (compared with top ones). Many studies show that these groups traditionally have a lower tendency to choose S&T subjects than the "white male, upper-class, high-academic achiever" student.[5]

Another result of the extension of tertiary education is the diversification of the types of courses offered. The creation of new courses and departments with better marketing and new equipment may benefit from young people's attraction to novelty.

Post industrialism: A change in values?

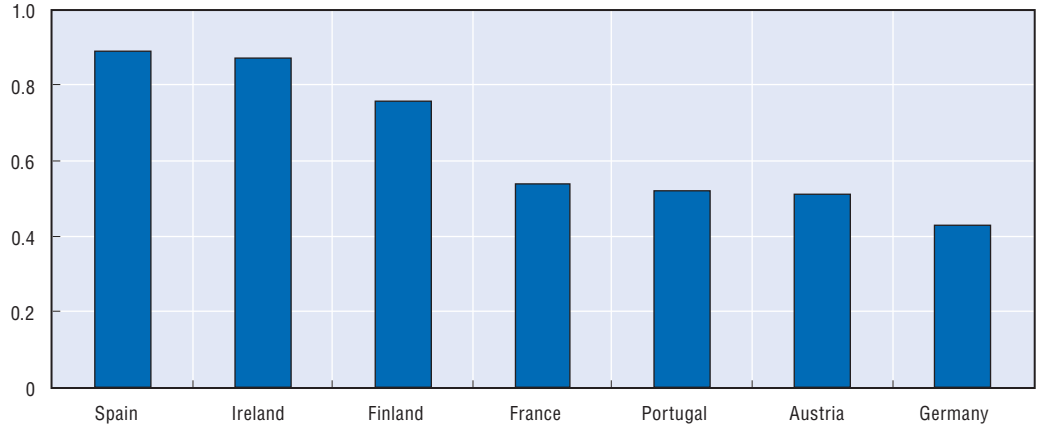
According to Eurobarometer, 13% of the population of the EU15 can be classified as postmaterialist and 58% as "mixed" *i.e.* their answers to the survey some patterns of postmaterialism and some patterns of materialism (Eurobarometer, 2006). Much has been written about a change in young people's values, with two extremes negatively affecting S&T studies. On the one hand, people who reject materialism and give priority to personal development and private life over work are reluctant to accept heavy workloads and their implied sacrifices, such as those connected with science studies and careers.[6] Some countries, such as Japan, also report a growing emphasis on spiritual values among the general public.[7] Another group of young people is more and more inclined to prioritise career and money, but will prefer business studies, economics, law or medical studies, as science is not perceived as rewarding enough.[8] Both of these trends could be analysed as reactions to economic crisis and doubts about the future.[9]

Socio-economic composition of student populations

Social mobility as reflected in access of students from different socio-economic backgrounds to higher education varies considerably from one country to another. Although data on this question are limited to only nine countries, a marked pattern emerges. In most countries, there is a strong social selection into higher education whereby students from homes with higher educational backgrounds are over represented and students from a working-class ("blue-collar") background are underrepresented (in many cases severely so). Some countries appear to do better in this respect, with Ireland and Spain performing substantially better in terms of providing higher education for all, irrespective of students' background. In Austria, France, Germany and Portugal on the other hand, students from a blue-collar background are about half as likely to be in higher education than their share in the population would suggest.

Differences between countries in duration of higher degree programs, the types of degree that students pursue and the existence of non-university institutions all play a role in explaining participation in higher education by students from less advantaged backgrounds. Students from lower educational family backgrounds are more frequently enrolled in non-university institutions and this might, to some extent, explain differences in the socio-economic status of students between countries, as not all countries provide this opportunity in higher education. Countries that have expanded their tertiary education in recent years will also, by default, have a higher intake of students from less advantaged backgrounds.

Figure 2.1. **Ratio of students' fathers in blue-collar jobs**



Source: Eurostudent, 2005.

Among the countries for which data are available on the socio-economic status of students in higher education, it appears that raising standards of lower secondary education in all schools is important for having more students from less affluent backgrounds in higher education. However, comparable data on the socio-economic status of students in higher education in different countries are rare and more information and better country coverage are needed to understand what the main social, psychological and other obstacles are in having a more equal distribution of students in higher education.

In many countries, a significant and continuously increasing part of the population is also born of immigrant parents or are immigrants themselves. Due to economic, social and cultural factors, the study patterns of students from immigrant backgrounds may differ strongly from the general pattern and from one group to another, but these differences seem to vary significantly from one group to another, and little insight will be gained from treating "immigrants" as a homogenous category.

Students' expectations regarding their level of education

Over half the students aged 15 in OECD countries (57%) expect to complete tertiary education, but the rate varies widely, from 95% in Korea to 21% in Germany. The wide variation in students' expectations may seem surprising, but expectations are influenced by the prospects of finding well-paying jobs for individuals with varying levels of education in a given country, cost-benefit ratios for students in different countries to pursue higher education, availability of public and private funding, and the nature and structure of the education systems (*e.g.* how much choice students have in choosing their education and school). Moreover, countries differ in the age at which decisions regarding higher education are made by or for students. Finally, in countries where a large proportion of school-leavers traditionally enter vocational programmes, student aspirations for academic programmes may be lower.

Student-characteristics associated with their expectations

Student expectations can be influenced by their academic performance, gender, socio-economic status, and whether they come from an immigrant background or not. In 21 OECD countries for which data are available, females expect to complete ISCED 5A or 6

more than males, except in Japan, and females also have higher expectations regarding future careers. Overall, these results mirror other attainment-related statistics. Females today are far more likely to have completed tertiary education than females 30 years ago with more than twice as many females aged 25-34 having completed tertiary education than females aged 55-64. University-level graduation rates for females also now equal or exceed those for males in 21 of the 27 OECD countries for which data are comparable.

Students with a relatively higher socio-economic status are at least twice as likely, compared to those with a relatively lower socio-economic status, to expect to complete ISCED 5A or 6 in all but one country. Analyses of PISA data show that even when students have the same ability *level, students from lower socio-economic backgrounds are still less likely to expect to complete a high level of education than are students from more advantaged backgrounds.*

In at least half of the 14 OECD countries with a sizeable population with an immigrant background among 15-year-old, both first- and second-generation students are more likely to expect to complete ISCED 5A or 6 than are their native-born counterparts.

2.1.2. Changes in S&T

The science and technology work market

Despite the relative decline of some branches, there is no lack of opportunity to pursue a career in S&T in an industrial setting. Industry and R&D remain strongly linked and the manufacturing sector accounts for the largest part of R&D spending in most OECD countries. Within manufacturing, the high- and medium-high technology sectors continue to grow in terms of their contribution to value added and total R&D performance relative to medium-low and low-technology industries. High-technology industries account for over half of total manufacturing R&D, and at the same time, knowledge-intensive industries are growing in importance.

The continued progression towards a knowledge-based economy and the expansion of knowledge-based industries has raised demand for professional workers of all kinds, including scientists and engineers. Across the OECD rates of growth of employment in professional occupations has outpaced employment growth overall, often by a wide margin. In the EU15, for example, professional employment expanded at an average annual rate of 2.7% between 1995 and 2004, whereas overall employment increased by only 1.1%. In the United States, professional employment grew at 2% per year, twice as fast as overall employment.

In 2002, approximately 3.6 million researchers were engaged in R&D in the OECD area, up from 2.3 million in 1990. This corresponds to about 8.3 researchers per 1 000 employees, *versus* 7 in 1995. Most were engaged in the business sector and just over 25% were engaged in the higher education sector. Nevertheless, the low relative levels of business researchers has remained an issue in the EU, especially as the region attempts to meet its objective of boosting R&D spending to 3% of GDP by 2010 – a task that by some estimates would require an additional 700 000 researchers, mostly in the business sector.

In terms of simple job opportunities, S&T would seem to be an attractive option, but many of the jobs offered are temporary. In October 2005 in Italy for example, over 100 000 students and "precarious" researchers staged a demonstration against their working conditions and researchers in other European countries have also mobilised, *e.g.* the "Save Research" movement in France. In October 2003, the Spanish government adopted a special Statute to regulate the employment and social security cover of research

trainees/interns in public institutions, who previously had no rights in this area, but researchers in the private sector were not included in the measure. Due to media coverage, the S&T work market may also be perceived as subject to strong international competition (brain drain/brain gain) and, coupled with salary expectations lower than other, less arduous professions, S&T jobs may seem less attractive.

Image of and interest in S&T

Interest in science and technology and the decision to study S&T subjects are undoubtedly influenced by the general perception of S&T in the public mind. It is therefore instructive to look at how people regard science and technology and where they get the information on which this attitude is based. In 2001, the US National Science Foundation and the European Union's Eurobarometer both studied these issues in their respective regions, and their general conclusions probably apply to other OECD countries too. The overall conclusion is that public attitudes are generally positive, more so in the US than in Europe, as shown in reactions to the four statements below:

1. *Science and technology are making our lives healthier, easier, and more comfortable*. In the United States, 86 per cent of respondents agreed, compared with 71 per cent of Europeans. In addition, one in five Europeans disagreed, nearly twice the proportion of Americans who disagreed.
2. *With the application of science and technology, work will become more interesting*. In the United States, 86 per cent agreed, compared with 71 per cent in Europe.
3. *Thanks to science and technology, there will be greater opportunities for future generations*. In the United States, 85 per cent agreed, compared with 72 per cent in Europe.
4. *The benefits of scientific research outweigh any harmful results.* In the United States, 72 per cent agreed, compared with 50 per cent in Europe. In addition, only one-tenth of Americans disagreed, compared with one-fourth of Europeans. Although the percentage of Americans agreeing with this statement has held steady at more than 70 per cent since 1988, agreement has declined in Europe, falling 11 percentage points between 1992 and 2001.

The surveys also suggest certain relationships between knowledge of S&T and belief in its benefits.[10] In Europe, the more people know about science, the more likely they are to believe in its benefits, whereas Americans are generally more likely than Europeans to view S&T as beneficial, whatever their level of knowledge. The one exception is the statement about the benefits of research outweighing harmful results, where the relationship between knowledge and agreement is stronger in the United States than in Europe

Despite the overall positive opinion, both surveys also highlight reservations:

- *We depend too much on science and not enough on faith.* In the United States, 51 per cent of respondents agreed with this statement, compared with 45 per cent in Europe.
- *Science makes our way of life change too fast.* In the United States, 38 per cent agreed, compared with 61 per cent in Europe.

The number of people showing no interest in science is also worrying, particularly in Europe where 45% of people feel they are neither interested in nor informed about science and technology.

There is also evidence that younger generations may have less positive views than their elders on the social utility of S&T. In a public opinion survey in Japan in 2004, 58% of

18-19 year-olds agreed that "New problems in society will be solved by S&T", while 64% of the 20-29 age group, 69% of 30-39 year-olds , and over 70% of 40-69 year-olds agreed.

Despite this, image and motivation surveys show that the perception of science and technology remains largely positive among young people. Science and technology are considered important for society and its evolution, despite concerns in specific areas, often linked to negative environmental and societal consequences of S&T. It is interesting to note that OECD countries seem to have a less positive image of S&T than some less economically advanced countries (SAS and ROSE surveys).

The Nestlé Social Research Programme in England (Haste, 2004) provides an interesting complement to the ROSE study. It examined the opinions about science (rather than education) of interviewees aged 11 to 21, including university students and people no longer in full-time education and came up with a typology of four groups:

1. Green. This group links ethical concerns, the environment, and scepticism about interfering with nature. It is particularly associated with girls under the age of sixteen and with those who would be interested in a job in science.
2. Techno-Investor. People in this group link enthusiasm for investing in technology (especially space-related) and in science research, with beliefs about the beneficial effect of science and trust in both scientists and government. Boys under sixteen and young men over this age and in the workforce are strongly represented.
3. Science-Oriented. This group is characterised by interest in science programmes on television, and science fiction, and a belief that a "scientific way of thinking" can be applied widely. Males over sixteen in full-time education and in the workforce dominate this group.
4. Alienated from science. As the name suggests, this group reflects boredom with science, and scepticism about its limitations. Younger girls and older females in the workforce not interested in a job related to science characterise this group.

From the point of view of encouraging more students to continue studying S&T, the various typologies give a mixed message. Many, if not most, students are interested in S&T to some extent, but only a minority see it as relevant to their personal concerns or choice of further study and career.

Similarly, scientists are also among the professionals the public trusts most,[11] even though their prestige has declined (higher management or government positions are rarely held by scientists or engineers, and media reports on S&T events do not focus on the researchers themselves, who are thus very rarely known by name).

2.2.1. S&T and the media

Knowledge and perceptions people of S&T come from principally from the media, notably television, which was the leading source of S&T news for 44% of Americans and 60% of Europeans, followed by written media (principally newspapers and magazines). Perhaps surprisingly, the Internet was the main source of S&T news for only 9% of those surveyed in the US and 17% in Europe, although almost half the US sample said they would use the Internet as their main source when looking for information on a specific subject such as global warming. These figures have probably evolved since the surveys, given increased access to the Internet and the development of online information sources such as Wikipedia. Science documentaries are increasingly popular, with some series enjoying

prime time broadcasting on national networks in certain countries, and films like "The March of the Penguins" and "An Inconvenient Truth" doing unexpectedly well at the box office. However, the educational impact of popular TV series may be limited if these programmes are viewed principally for their spectacular special effects rather than scientific content. The same may apply to visits to science museums, which may simply be science as entertainment rather than learning.

Unfortunately, scientific issues are often sensationalised, trivialised, or misunderstood by the media. The stories chosen usually fall into one of three categories: breakthrough, silly or scare. Scare stories give a poor image of science, reinforcing the stereotype of the "mad scientist" whose research is dangerous for human health or the environment. Likewise, trivia such as the scientific formula for how to eat ice cream or write a sitcom present scientists as eccentrics and their research as futile. Breakthrough stories give an image that is positive, but just as inaccurate as scares and trivia, ignoring the way ideas and intuitions emerge, are formulated as hypotheses and then tested, vindicated, revised or rejected over a period of time. When S&T as a profession is the subject of the media, it is usually for a negative reason, such as cuts in budgets.[12]

Scientific ignorance among the media and public impoverishes debate about serious choices facing society (*e.g.* presenting the GMO debate as Frankenstein food *versus* obscurantism) but can also have dangerous consequences in a more direct manner. In 1998, the UK media widely reported a study that associated the MMR (measles, mumps rubella) vaccine with autism and bowel disease in children. The reports gave the impression that the scientific community was evenly divided as to the safety of the vaccine, whereas the research in question was widely criticised, no other studies corroborated its findings, and 10 of the 12 authors of the paper rejected the conclusions. Nonetheless, the rate of vaccination dropped dramatically, and in June 2006 British paediatricians issues an open letter criticising the scare stories and calling on parents to vaccinate their children – national coverage was down to 83% while 95% coverage is needed to provide protection to the whole community, and the number of measles deaths was rising.

One encouraging sign of public interest in S&T is the expanding market for books dealing with science and technology. Stephen Hawking's *A Brief History of Time*, first published in 1988, sold over 9 million copies (although how many of them were actually read is a different matter) leading publishers to devote more resources to the sector. As with other sections of publishing, much of the output is formulaic, derivative and uninspired, but books about science can both stimulate public debate and foster vocations.

2.2.2. Ethical issues

The dangers of science and technology are highlighted in tales from widely different times and cultures, such as Prometheus and Pandora, the Golem, or Frankenstein. Some of the questions they raise are still being debated today, but as the pace of scientific discovery accelerates and the technical capacity to transform knowledge into applications grows, the possibility of "man playing God" seems less and less fantastic. This has lead to a number of debates concerning the ethics of modern science, notably concerning the biotechnologies, *e.g.* genetic modification of plants and animals, cloning, stem cell research, etc. Other controversies include tests on animals, weapons development, nuclear power, and surveillance systems. Public and individual attitudes can often be ambiguous, for example people who feel uneasy about genetic manipulation may be prepared to use

medical treatments depending on such research themselves or for their family. In general, though, the image of science and scientists evoked by controversial questions is negative among a significant share of the population. Sometimes this can have direct consequences on scientific work, for example if GM crops are destroyed or animal testing laboratories are bombed or their animals released.

The issue is complicated by two further dimensions. First, in today's society any authority tends to be challenged, including scientific authority. When added to mistrust of government and other "official" views and sources of information, this means that the case in favour of a given scientific or technical position can be treated with suspicion rather than an open mind. Second, scientists can provoke or aggravate negative attitudes by seeking to exclude non-scientific arguments from topics where strong moral, ethical or social concerns are involved.

Box 2.2. **What secondary students think of S&T**

Results for England provide a reasonable approximation of attitudes in the industrialised world in general, although there may be important differences in any given result when comparing a particular country with the group, or within a group of countries (Jenkins and Pell, 2006).

- Most students agree that science and technology are important for society and are optimistic about their contribution to curing diseases such as HIV/AIDS and cancer. Science and technology are also seen as creating greater opportunities for future generations and as making everyday life healthier, easier and more comfortable.
- There is a lower level of agreement that the benefits of science are greater than possible harmful effects, although a majority of both boys and girls hold this view. Only a minority of boys and girls agree that science and technology will help to eradicate poverty and famine in the world.
- Students' positive views about science, technology and society are not reflected in their opinions about their school science education. While this is regarded as "relevant" and "important" by most students, most boys (and rather more girls) do not like it as much as other subjects.
- There is a group of students who like science better than other school subjects but do not find school science interesting.
- There is a minority of students who are strongly supportive of science, like their school science, want as much science as possible at school and envisage themselves working in the future as a scientist or technologist. For these students, the commitment to science is, at best, only weakly associated with notions such as utility and relevance.
- Most students do not agree that school science is a difficult subject.
- Most boys and girls disagree that school science has made them more critical and sceptical, opened their eyes to new and exciting jobs or increased their appreciation of nature.
- When asked what they wished to learn about, there are marked differences in the responses of boys and girls. For girls, the priorities lie with topics related to the self and, more particularly, to health, mind and well-being. The responses of the boys reflect strong interests in destructive technologies and events. Topics such as "Famous scientists and

Box 2.2. **What secondary students think of S&T** *(cont.)*

their lives" and "How crude oil is converted into other materials" are among the least popular with both boys and girls.

- There are major differences in the out-of-school experiences of boys and girls. Those of girls are associated with activities involving the natural world, such as planting seeds, or crafts such as knitting or weaving. In the case of boys, activities that might be described as mechanical are to the fore, although the engagement of girls with the use of simple tools should not be overlooked.
- When asked about a future job, both boys and girls attach importance to having time for a family and to using their talents and abilities. However, helping other people is more important for girls than boys and they attach less importance than boys to becoming famous.
- Both boys and girls disagree strongly that threats to the environment are not their business. However, such disagreement is not reflected in a corresponding general willingness to sacrifice many goods to solve or alleviate environmental problems. There is also, at best, only a moderate level of interest in learning about a range of environmental issues, save for the possible radiation dangers associated with mobile telephones and the protection of endangered species of animals.
- Students are optimistic that solutions can still be found to environmental problems but girls are less confident than boys in the ability of science and technology to do so.
- Some students see environmental problems as exaggerated, the cause of too much anxiety and as best left to experts to resolve. Others attach more importance to the role of individuals in addressing environmental problems and are willing to make personal sacrifices to this end.
- When asked to choose a field of research they would pursue as a scientist, most students chose the treatment and cure of disease or aspects of space science. The former was much more popular with girls than boys but the difference was much narrower in the case of the latter. The two most common reasons for the choice of field of research involved references to curiosity/interest/excitement and to helping people or animals.

Conclusion

As mentioned above, a wide variety of factors influence choice of studies and career. In general, there are no simple one-to-one correspondences between these phenomena, except perhaps between increasing complexity and the exponential increase in knowledge. Globalisation, for example, allows a greater access to different cultures and experiences, something young people value, but it also means more competition. Likewise, variety may imply uncertainty.

2.2.3. The image: S&T, S&T professionals, and S&T careers

A positive if blurred image of scientists

The general public has little or no idea of what scientists actually do in their working life (and for mathematicians, the situation is even worse) and very few scientists are known by name. Young people, like their elders, thus have a stereotyped image that swings between the two visions of a man in a white lab coat staring intelligently at some exotic glassware full of scientific-looking liquid, or of a wild-haired eccentric solving mile-long

equations but incapable of posting a letter. The popularity of television series featuring forensic science may change this somewhat, but in daily life, the only science professional most young people will come into contact with is their teacher, despite their interest in S&T subjects.

Surveys of experience and opinion among young Japanese highlight the remoteness of science and scientists: only 15% of citizens agreed or somewhat agreed with the statement "Scientists and engineers are close to the public and are familiar". Yet, despite the reservations mentioned above, scientists are held in relatively high esteem. For example, the US General Social Survey investigates public confidence in the leadership of various professional communities. The scientific community has ranked second or third every year since 1973 with a score of around 40%, which is higher than medicine (37% in 2002), the federal government (27%) or the Supreme Court (37%). In August 2002, a Harris Poll ranked scientists as the most prestigious of 17 professions, and engineers seventh. This does not necessarily mean that people trust scientists more than others: another poll by the same company in November of the same year only ranked scientists fifth out of 21 professions when the sample were asked to say who they thought the members would tell the truth (scientists were still ahead of the President and judges).

The US polls show a general perception, so it is interesting to see how the public react to a specific, highly-publicised case. In 2001, the European Commission conducted a survey to assess opinion about responsibilities for the BSE outbreak ("mad cow disease"). About half (51%) of those surveyed agreed that "scientists bear a great deal of responsibility", compared with 74% for the agri-food industry, 69% for politicians, and 59% for farmers. The higher people's knowledge about science, the less they were likely to blame scientists. Despite all the media coverage of BSE, 45% of respondents did not feel well-enough informed to give an opinion. This is reflected to a large extent in what people thought should be done to avoid a similar crisis in the future: 82% thought that the industry should be better regulated, but other replies emphasised the role of scientists and scientific information, with 89% replying that "scientists ought to keep us better informed about the possible hazards of certain scientific or technological advances"; 86% that scientists should "communicate their scientific knowledge better"; and 72 per cent that politicians should "rely more on the opinion of scientists".

It is one thing to question the "external" perception that young people have of S&T and S&T professionals, and another to analyse the more personal and internal perception of how young people relate to S&T as a field "for them". Career choice is the joint answer to two questions: "Can I see myself as…?" and "What can I do with…?" (What can I be? What can I do?) The aim of this study is not to analyse the economic efficiency of the choice of an S&T career against the other possible choices, but rather to outline the perception that young people have of S&T careers, as a factor that may significantly contribute to their choice of S&T studies. Nevertheless, when relevant, and when such data are available, the link between young people's perception of S&T careers and the actual situation will be made.

A negative if ill-informed image of science careers

There is a sharp difference between the positive opinion of young people towards S&T and their actual wish to pursue S&T careers. Although S&T professions continue to generate great interest among youth in developing countries, this is no longer the case to the same level in industrialised countries, with an even weaker taste expressed by girls

(except for health-related professions). Many young people have a negative perception of these careers and lifestyles. Incomes are perceived as low relative to the amount of work involved and the difficulty of the required studies. Few pupils have a full or accurate understanding of science-related professions, and many are largely unaware of the range of career opportunities opened up by S&T studies.

Positive decisions to pursue S&T studies and careers are often linked to better knowledge. Several surveys suggest that having a parent or family member working in S&T increases the chance of a student choosing S&T. Students also indicate that professional contacts have a strong impact on their choices. This is especially important for girls who may lack adequate role models in these professions. The decision to choose S&T studies also depends on students' knowledge of careers outside S&T traditional professions. Thus, many students are sensitive to the range of professions opened up to them by various educational channels, and tertiary-level S&T studies are often wrongly perceived as leading to a very narrow choice of technical careers.

Box 2.3. **What they say about science careers**

What adults say:

To the question "what do you think is the main reason – if there is one- for the falling interest of young people in scientific studies and careers?", in the Eurobarometer study, about 50% of respondents gave "young people are less interested in working in the scientific field" and 42.5% gave "salaries and career prospects are not sufficiently attractive in the scientific field" among their three first answers.

What scientists say:

Nearly all the scientists asked in the Bayer Facts study in 1998 (91% of female respondents and 95% of male) say, if they could begin their career all over again, they would be very likely or fairly likely to choose a career in science.

What young people say:

The main criteria for choice of a profession are:

- Passion/interest.
- Working conditions (hours and autonomy).
- Income and social position.
- Security/stability.

In some studies, young people say that, as much as parents, teachers or friends, what influences them in their career choice is meeting real people working in the considered fields or professions. Then, they find useful such opportunities as meeting professionals and visiting companies.

The view that emerges from surveys and informal information-gathering across OECD countries is that while young people have a positive view of S&T and its contributions to making life better, the image of S&T as a profession is negative, with workers in these fields seen as doing boring, uninteresting work in unpleasant surroundings, cut off from other people. Technicians are further handicapped by the lower social prestige of their occupation. In spite of this, most adults would still recommend a scientific career to their children or to a young relative (77% in one Canadian study). When young people are asked

to list their criteria for choosing a profession, they cite passion/interest, working conditions, income and social prestige, and security/stability.

On these criteria, a career in S&T can seem less attractive than more fashionable professions thought to have a more stimulating lifestyle, such as working in the media. Science and technology can also be in competition for students who study S&T but chose a different profession. In some countries, a scientific major in high school is considered as criterion of academic excellence, and opens the way to valued opportunities outside the science field, health or business management, for example. For instance, in Japan, bright students in S&T courses often choose medical sciences or law and business courses over S&T at tertiary education level (Ogura and JST, 2005). The exact same phenomenon is true in France, where young people with an S&T major in high school may prefer later on to choose medical or business studies that are just as difficult as science, but may have a better return on investment (Ourisson).

Interest in S&T is likely to be greater if the young person has role models and direct knowledge of the career opportunities offered by S&T. Several surveys suggest that having a parent or family member working in S&T increases the chance of a student choosing S&T studies or a career involving S&T. Students also indicate that professional contacts have a strong impact on their choices. This is especially important for girls who may lack adequate role models in these professions.

Apart from underestimating the number and variety of professions within S&T, young people are frequently unaware that many non-scientific professions such as nursing or economics use scientific knowledge and require science studies. (Euroscene, 2005). The subject for which job opportunities are least well-known is physics, whereas life and earth sciences are the best ("Outlook on scientific and technical professions" CCSTI Grenoble.) Unfortunately, S&T teachers are sometimes reluctant to advise their students about S&T careers, afraid they do not have enough information and might give wrong advice (Munro and Elsom, 2000).

Even some students who initially decided to study S&T decide to switch to another discipline on the basis of misconceptions about what their future jobs might be like. In 1997, Elaine Seymour conducted a survey among students who chose to give up their S&T majors. She reported that:

> "*In describing the nature of the work available to graduates, switchers in all SME majors drew upon a set of myths and stereotypes. We found the same set of beliefs strongly represented on every campus and across all SME disciplines. The mythology included images of scientific workers as automata doing solitary work in confined, sterile, prison-like surroundings. Work was imagined to be intellectually dull, repetitive ('brain-numbing') and defined by unknown others in a remote organisational hierarchy. Working conditions were conceived in terms of long hours under stressful conditions with little job security. Metaphors of entrapment, life sentences and solitary confinement permeate the descriptions.*" (Seymour and Hewitt, 1997).

According to Seymour, students imagined that, in order to pursue SME careers, they would have to embrace a persona which was alien to their own personality. They portrayed engineers, especially, as dull, unsociable (often materialistic) people who lacked a personal or social life and were unable to relate comfortably to non-engineers. They were also portrayed as uncreative people, who avoided or decried the idea of a broader education. Some thought that science tended to attract people who already had these personality traits. They also saw themselves and their peers beginning to develop these undesirable

characteristics as a consequence of the lifestyle they were constrained to adopt in order to survive in the major.

These barriers to choosing a to study and work in S&T were summarised by the Swiss Coordination Centre for Research in Education in a report on mathematics and science in Swiss schools (CSRE, 2003):

- Lack of a social background that stimulates children's interest in S&T, particularly for girls.
- No correspondence between the image of S&T professions and what young people seek in a career (independence, self-fulfilment, varied activity).
- Unsatisfactory salary and career prospects.
- A school learning environment that does not arouse and nourish interest in S&T.
- Discouraging conditions of study, and lack of perspectives in pursuing a scientific career, particularly for women.
- Real or imaginary obstacles posed by a profession or course of study to reconciling work and family life, again for women in particular.

How do young people choose a career?

The Relevance of Science Education (ROSE) project provides insights into some of these points in its surveys of how students aged 15 in around 40 industrialised and developing countries think about their future job, and how what they think about careers in S&T (it also examines their attitudes to S&T teaching, discussed in the next section.) The sections entitled "My future job" and "Myself as a scientist" in the Irish survey are typical of results for OECD countries generally (Matthews, 2007).

Both boys and girls are keen to make use of their individual talents and to seek personal involvement and some degree of autonomy in their future careers, as shown in topics entitled "Using my talents and abilities", "Making my own decisions", "Working with something I find important and meaningful", and "Working with something that fits my attitudes and values". At the same time, responses to "Having lots of time for my friends" and "Having lots of time for my family" also emphasise that it is not just financial or some other extrinsic reward that these students hope to obtain from employment, although "earning lots of money" is highly important (much more so for the boys).

Many responses convey a strong sense that students value personal and social relations as much, and perhaps more, than material rewards. As Matthews points out, while this could be dismissed as the naivety of youth, it is an emphasis that potential employers might reflect upon if they are to encourage students to opt for careers in physical science and engineering. These two fields are not renowned for involving students on a deeply personal level or for putting emphasis on their "human dimensions".

Neither boys nor girls are looking for "an easy option", which is a positive response, given that their experience of school science generally leads about half of them to regard the subject as difficult and demanding. If this cohort is representative of the wider population of students, potential employers may have trouble reconciling the need to give students a feel for the variety of challenging and interesting jobs available following third level study, while avoiding giving them the impression that the technical expertise required for such jobs is demanding and too far removed from direct connection to human needs.

Gender differences are marked in some responses. Girls are more averse than boys to jobs that they think involve "building or repairing objects" or "working with machines or tools". On the other hand, students of both genders are more positively oriented to "making, designing or inventing". As with any questionnaire where respondents have to imagine themselves in a given situation, it is not possible to be sure which images the questions conjure up in the minds of the students. If, for example, students envisage using picks and shovels or repairing cars then the results reflect well-established patterns in studies of gender bias. For example, a number of health professions that girls are attracted to also involve "working with machines and tools", so the replies may have been different if say medical equipment had been mentioned as an example.

Nonetheless, the fact that the questions are not "contextualised" means that the replies give a useful description of how young people react spontaneously to a number of issues. Science educators and potential employers have to bear this in mind when trying to make S&T more attractive. One of the key messages is that the relevance of S&T to students' concerns should be a central part of how science is taught and represented, not an optional extra brought in occasionally to try to boost flagging interest.

Myself as a scientist…

Students were also asked to imagine themselves working as a scientist, but in this case, rather than being asked to agree or disagree with a number of statements, they were set the following task. Assume that you are grown up and work as a scientist. You are free to do research that you find important and interesting. Write some sentences about what you would like to do as a researcher and why. "I would like to … Because…".

Both boys and girls expressed an interest in biological themes to a far greater extent than in themes related to chemistry or physics. Only six replies for girls and nine for boys mentioned "pure" chemistry-related or physics-related research, and the number of choices related to technology for girls was just fifteen. The total of 50 for the boys is considerably greater, but still far below the 173 biology-related entries mentioned by boys (223 for girls).

Given that the students gave free, unprompted responses, the results are worrying for physics, chemistry, engineering and technology are concerned. The questionnaire provides no clues as to whether students did not mention these areas because of lack of interest in them, or if they were simply ignorant of research and work in these fields. If ignorance is a major reason, some of the blame must be laid on the media, and the kind of reporting mentioned earlier. On a more positive note, both boys and girls are interested in space and astronomy themes (41 for the girls, and 55 for the boys) and given that space and astronomy as essentially associated with physics, then these topics could be given more emphasis in physics curricula, especially if the subject is to be made more appealing to girls.

The reasons given by both girls and boys for wanting to work in the areas of S&T they chose were dominated by their intrinsic interest. Almost the same percentage of girls (47.9%) and boys (46.9%) gave "curiosity, interests, seems fun, want to, exciting" as their reasons. Once again, the perceived importance of their choices for society and their role in helping people, animals, etc were very important. This tends to emphasise the perception that biology is related to people and living things, with a clear link to medicine and other health-related developments in society, whereas physics and chemistry seem to lack "social" links.

This is in part due to the way different scientific disciplines are still taught more or less independently of each other, as in the 19th century, while in reality they overlap and converge. It may be possible to exploit the relative popularity of biology and life sciences to interest students in careers or studies in other sciences, *e.g.* by showing how an exciting new branch of medicine such as nanomedicine or gene therapy uses inputs from chemistry, engineering and so on. Likewise, even apparently abstract notions from the physical sciences are vital in developing many of the electronic products prized by students.

The table below summarises what the students would study if they were scientists, and the reasons for their choices. At first sight, one particularly encouraging result is the zero response for "Do not want to do research", but this probably has more to do with the context of the exercise than students' interest in S&T, *i.e.* given that they had to imagine themselves as a scientist, they naturally imagine that a scientist does research.

Table 2.1. **Myself as a scientist**

	Number (*percentage*) of responses			
	Girls		Boys	
Biology: human, body	34	*10.3*	31	*8.7*
Diseases, medicine, cures	135	*40.9*	81	*22.6*
Microbiology, gene technology	9	*2.7*	25	*7.0*
Animals, plants, nature	39	*11.8*	29	*8.1*
Other biology-related	16	*4.8*	7	*2.0*
Technology: computers, electronics, new technologies	5	*1.5*	18	*5.0*
Motors, buildings, roads, cars, transport	2	*0.6*	17	*4.7*
Weapons	0	*0*	5	*1.4*
Other technology-related	8	*2.4*	10	*2.8*
Environment	10	*3.0*	14	*3.9*
Earth, weather, climate	3	*0.9*	2	*0.6*
Chemistry: atoms, reactions, etc.	3	*0.9*	4	*1.1*
Physics: electricity, heat, etc.	4	*1.2*	5	*1.4*
Space, stars, planets, black holes, space travel	41	*12.4*	55	*15.4*
Psychology, human behaviour	12	*3.6*	4	*1.1*
Invent things	0	*0*	3	*0.8*
Do experiments, work in a laboratory	1	*0.3*	1	*0.3*
Paranormal, philosophical, mysterious, wonder	13	*3.9*	12	*3.4*
Social and economic sciences	1	*0.3*	2	*0.6*
Do not want to do research	0	*0*	0	*0*
Other	18	*5.5*	30	*8.4*
Responses giving reasons why choices have been made				
Curiosity, interests, seems fun, want to, exciting 158	158	*47.9*	168	*46.9*
Related to the profession I want	13	*3.9*	7	*2.0*
Important in general for society/humanity	48	*14.5*	47	*13.1*
Help people, animals etc	103	*31.2*	77	*21.5*
Get rich, popular, famous	0	*0*	6	*1.7*
Other	17	*5.2*	34	*9.5*

Source: Royal Irish Academy (2007).

Careers advice

Students are more likely to study S&T if school career services inform them of the range and interest of professions such studies can lead to. Evidence presented to the Science and Technology Committee of the British House of Lords from a number of sources

suggests that career services are failing students in this respect. Some of the points raised refer to the particular arrangements of UK services, but many of the concerns would probably find an echo in other countries too. The Institute of Physics (IoP) for example claimed that "students are not being given accurate careers advice at a sufficiently early age to allow them to make informed choices ... careers advice tends to be reactive and does not give students a full picture of the consequences of subject choices". Drawing on a report conducted in 2000, the IoP noted that science teachers did not see themselves as a source of advice because they did not feel able "to keep up with careers information" and the Science Learning Centres added that there should be "better careers information available to science teachers, who are often the people to whom students ... turn first when considering whether to opt for science subjects".

Careers advisers, meanwhile, overwhelmingly had humanities or social science backgrounds – the IoP noted that just one in ten of those surveyed had science degrees. The consequences of this imbalance were that "90% of careers advisers ... did not feel confident with giving advice about science and engineering careers" or even advised students not to do the sciences because they are more difficult.

If (to caricature) S&T are perceived as difficult, boring and irrelevant to most students, even those studying them, then the job of careers advisors and others involved in orienting young people's choices is extremely difficult. An additional problem is that most of the professional counsellors employed by schools come from a non-science background and may feel uncomfortable about giving advice on these careers. Likewise, science teachers may feel that they lack information on the comparative merits of various options, including S&T ones. The result is that students who do not have access to role models or information and encouragement from parents or outside the school are less likely to choose S&T.

One way to encourage greater participation could thus be to provide the various persons who advise students on choices of study and career with specific training in what S&T is and what it has to offer. Apart from careers and orientation professionals (and of course the students), this effort should be extended to students' parents or carers.

Family environment and role models

As mentioned above, the family can have a strong influence on choice of career. A survey of S&T students in higher education carried out for the Global Science Forum (BEST, 2005; Annex B) included questions on parents' occupations. Almost one out of two respondents (43.5%) had their father working in the S&T field and a almost a quarter (24.9%) their mother. The survey also shows the importance of other socially-related factors such as the knowledge of S&T professions (important in shaping the choice of 77.8% of respondents) and recommendation/support from the family (75.2%).

Conclusions

The image of S&T at the various levels of education, the image of S&T professionals, and the image of S&T careers all need to be addressed. There is a paradox here, since image and motivation surveys show that the perception of science and technology remains largely positive among young people. Science and technology are considered important for society and its evolution, despite concerns in specific areas such as possible negative environmental and societal consequences. Scientists are also among the professionals the public trusts most, even though their prestige has declined. Higher management or government positions

are rarely held by scientists or engineers, and media reports on S&T events do not focus on the researchers themselves, who are thus very rarely known by name.

Careers in S&T are still recommended by parents, but there is a sharp difference between the positive opinion of young people towards S&T and their actual wish to pursue S&T careers. Although S&T professions continue to generate great interest among youth in developing countries, this is no longer the case for industrialised countries, with an even stronger distaste expressed by girls (except for health-related professions). Many young people have a negative perception of these careers and lifestyles. Incomes are perceived as low relative to the amount of work involved and the difficulty of the required studies. This is true to some extent, especially in academic careers. Researchers seem poorly paid in relation to the skills and dedication asked of them in comparison to their peers in other professions, and emphasising nonmaterial rewards such as the intrinsic interest and excitement of the intellectual challenges may not be enough to persuade students. Moreover, some of the traditional attractions of science careers are being eroded by changes in the economy at large and how science is practised. For example, job stability in academia is restricted to those who have tenure, something that is becoming rarer and offered to fewer people than before, while the outsourcing of R&D by large companies means that private-sector research is increasingly done on the basis of short-term contracts rather than permanent positions. Autonomy and independence are also scarce in modern research, where the scientist is part of a team working on projects largely designed and managed by other people.

Nonetheless, research is only one of many S&T related options. Few pupils have a full or accurate understanding of science-related professions, and many are largely unaware of the range of career opportunities opened up by S&T studies. What they do know often comes from personal interactions (mostly S&T teachers, or someone in the family), or through the media. Scientists are usually portrayed as white men in white coats, and engineers as performing dirty or dull jobs. As S&T professions evolve quickly, S&T teachers and career advisors often lack up-to-date information to convey to their students. There can also be problems due to the fact that some science teachers may not feel the need to motivate students about the science as such when science is compulsory, or when it is an important component in access to higher education. In other words, motivation is purely instrumental, linked to getting good marks rather than fostering enthusiasm and interest.

The education system can do nothing about working conditions and career prospects in most S&T professions, but it can make sure that students have access to information about S&T careers that is accurate, credible, and avoids unrealistic or exaggerated portrayals, either negative or positive.

This information should be compiled by independent observers, and made available to the education community, parents and students. Better information on S&T jobs should also be provided through direct contacts with professionals, and governments should earmark resources for such outreach actions, and for assessing their effectiveness. This strategy is supported by evidence from surveys that suggest that having a parent or family member working in S&T increases the chance of a student choosing S&T and that professional contacts have a strong impact on students' choices. This is especially important for girls, who often lack adequate role models in these professions.

Governments are aware of these needs and have instigated numerous actions to improve the image of science and scientists in society (science weeks, science days, etc.),

Box 2.4. **Actions to improve the image of S&T and S&T professionals**

Let's talk science. Volunteer S&T professionals are given the opportunity to perform hands-on science activities in the classroom and in the community. Participants are provided with a realistic and positive role model, a point of contact with the scientific community and hands-on, interactive science education from a real scientist.

Environment meeting programme. Every year, the Tessenderlo Group sends out a delegation of its engineers to speak about their passion for chemistry to 14-15 year-old students. It also invites children from the local schools to visit its West-Limburg plants, as part of a national program aimed at primary school pupils (age 10-12 years). The children can visit the water purification installations and perform some laboratory tests.

About Life. These broadcasts feature documentaries about recent scientific achievements that are closely related to everyday experiences. Each edition of the programme is built around a prominent scientist who has been responsible for a scientific breakthrough in her or his specialist field.

Ciencia viva: National Scientific Awareness Campaigns stimulate and provide the opportunity for personal contact with science specialists and institutions in the different fields. These initiatives are free and open to all, with a focus on practical activities, providing active observation and interaction with specialists from the relevant fields. They are intensely publicized on the media (newspapers, radio, TV).

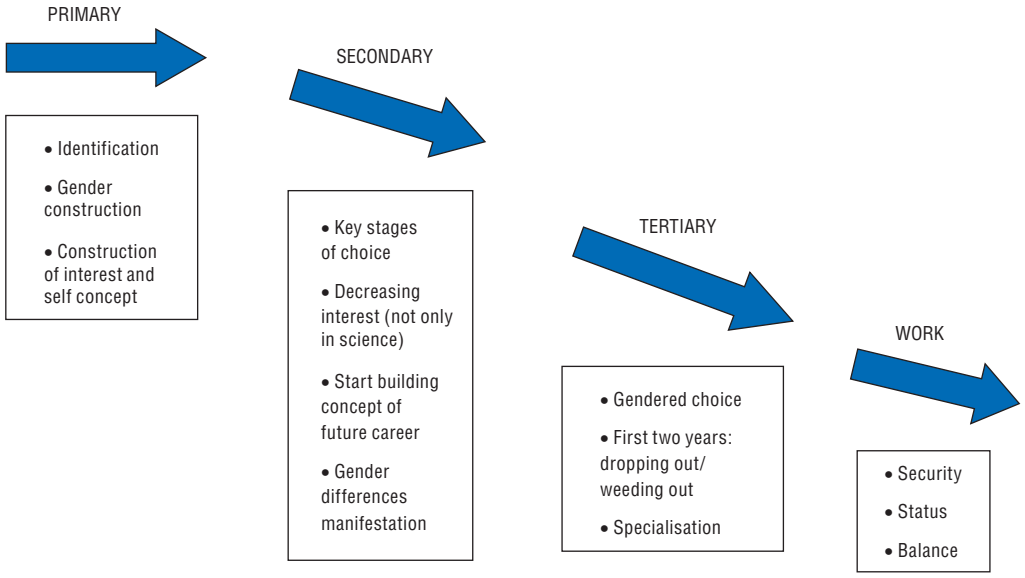
while many more undertakings come from professional scientific organisations. However, too often communication tends to focus on science itself, not on the reality of S&T professions. The actual impact of the various actions on both young people's attitudes and their choices of studies or careers is poorly evaluated, and communication between the various stakeholders is often inadequate. Follow-on actions need to engage all persons who are concerned by declining interest in science. A network of stakeholders (linking educational resource centres, the business community, S&T education specialists, and student and teacher communities), should be established to share information on best practices between countries and the various communities involved.

S&T education and curricula

The content and teaching of S&T at school are major factors in encouraging an interest in science and in the decision to pursue S&T. The main characteristics of education and curricula at the three levels can be summarised as follows:

- Primary level. Children have no choice, everyone must study science. It is often said that the principal objectives at this stage should be not only to acquire basic knowledge and skills, but also to stimulate interests and develop a positive attitude towards S&T.
- Secondary level. During adolescence, young people often experience a decline in their interest towards studies in general. Yet motivation seems to depend on the perception they have of the subject's relevance to their own life and society. This is a crucial period in many countries since it is the moment when young people choose their major subject. It is also the period when they build their personal set of values and goals and the representation of their future career. The secondary stage will be the main focus of this discussion.

Figure 2.2. **From primary education to work**



- Tertiary level. At this stage, in addition to criteria such as intrinsic interest, students also consider criteria like career prospects, expected earnings, and the risks associated with choosing a particular course of study.

2.3.1. Primary level

Children are naturally curious about scientific subjects (why the sky is blue, how grass grows, how ships float and planes fly, how TV pictures reach the home, etc.) and they usually enjoy practical work and learning through experiments. Primary school curricula often fail to take advantage of this, for a number of reasons. First, many primary teachers are uncomfortable about giving science lessons since in general they do not come from an S&T background and may have received little or no training in S&T subjects. They may adopt a number of strategies to deal with their lack of confidence in the classroom (Harlen, 1997).

Another reason, especially as children get older, is the temptation to allow assessment to dominate teaching. Experiments are not efficient regarding most assessment systems, which rely more on theoretical content which is easier to grade than work designed to promote autonomous thinking and working. Teachers often have to arbitrate between those activities that increase interest and motivation and those that increase the chance of success at the evaluation. Given that parents too judge how well the school is doing its job by exam results, theory-oriented teaching with little practical work ("talk and chalk") is likely to dominate, even if children's interest in science suffers.

2.3.2. Secondary level

Secondary is the most important level in determining whether students pursue S&T studies in that at this stage students can start choosing which subjects they wish to study. A variety of subjective and objective factors interact to influence how S&T are perceived at secondary level and whether students, if given the choice, decide to pursue these studies. Many of these are being studied in international comparative exercises such as the Norway-based Relevance of Science Education (ROSE) series of surveys, the US-based

Trends in International Mathematics and Science Study (TIMMS) and in work carried out by the Swiss Coordination Centre for Research in Education, as well as PISA.

ROSE is particularly interesting in this respect since it sounds the opinion of 15-year-old students on S&T and how it is taught in almost 40 countries to date, including many developing countries. It consists of sets of statements and topics that students rate on a scale from 1 to 4 depending on whether they agree/are interested or disagree/are not interested. The survey is divided into six themes: "What I want to learn about"; "My future job"; "Me and the environmental challenges"; "My opinions about science and technology"; "My out-of-school experiences"; and "If I were a scientist". The exercise provides detailed results on hundreds of items in the questionnaire, but some striking general conclusions can be drawn.

First, the students surveyed generally have a positive attitude to science and technology, but students in developing countries are more positive than those in developed countries. Moreover, the topics they are interested in are almost completely different, as the box below shows. Girls and boys from Ghana have practically the same topics in their lists, although the order is different, and they tend to be interested in things they may have to deal with in their daily lives, such as electricity (Anderson, 2006). English girls and boys have completely different lists from each other, although English girls do share some common concerns with Ghanaian girls and boys.

Second, within the developed countries, results are similar across countries, despite the great variety of education systems and performance in PISA or TIMMS. This suggests that factors other than how science is taught in school have a strong influence on students' perceptions, and that these factors are similar in all the developed countries.

Table 2.2. **The most popular S&T topics for girls and boys in Ghana and England**

Top 10 most popular topics in Ghana	
GIRLS	BOYS
How computers work	How computers work
What can be done to ensure clean air and safe drinking water	How my body grows and matures
How my body grows and matures	What to eat to keep healthy and fit
What to eat to keep healthy and fit	What can be done to ensure clean air and safe drinking water
How to exercise to keep the body fit and strong	How to exercise to keep the body fit and strong
How mobile phones can send and receive messages	How mobile phones can send and receive messages
How the eye can see light and colours	How things like radios and televisions work
Electricity, how it is produced and used in the home	Electricity, how it is produced and used in the home
What we know about HIV/AIDS and how to control	What we know about HIV/AIDS and how to control
How plants grow and reproduce	Sexually transmitted diseases and how to be protected against them
Top 10 most popular topics in England	
GIRLS	BOYS
Why we dream when we sleeping and what the dreams may mean	Explosive chemicals
Cancer, what we know and how we can treat it	How it feels to be weightless in space
How to perform first-aid and use basic medical equipment	How the atom bomb functions
How to exercise to keep the body fit and strong	Biological and chemical weapons and what they do to the human body
Sexually transmitted diseases and how to be protected against them	Black holes, supernovae and other spectacular objects in outer space
What we know about HIV/AIDS and how to control it	How meteors, comets or asteroids may cause disasters on earth
Life and death and the human soul	The possibility of life outside earth
Biological and human aspects of abortion	How computers work
Eating disorders like anorexia or bulimia	The effect of strong electric shocks and lightning on the human body
How alcohol and tobacco might affect the body	Brutal, dangerous and threatening animals

Third, despite the efforts of the past two or three decades to promote gender equality in education, there are still significant differences between boys and girls as to what they like and dislike about science and technology, and these differences are just as marked in countries that have the highest reputation for promoting equality as the rest. Results for Finland, for example, show that the biggest difference between boys and girls concern situations that relate to caring for ones own health, looks or beauty, with girls showing far greater interest than boys for "What to eat to keep healthy and fit"; "Plastic surgery and cosmetic surgery"; and "The ability of lotions and creams to keep the skin young". Boys interested in explosions, weapons and machines: "Explosive chemicals"; "How the atom bomb functions"; "Biological and chemical weapons and what they do to the human body"; "How petrol and diesel engines work"; and "The use of lasers for technical purposes (CD-players, bar-code readers, etc.)" (MIRROR Project, 2005).

The ROSE results for Finland shed more light on the subjects that interest students. Among the thirteen school subjects or disciplines included, the students were most interested in non-scientific or mystical phenomena, such as horoscopes and UFOs, as well as in things related to human health such as a healthy diet and substances detrimental to health. Among the sciences, the students, on average, were most interested in topics related to medicine and astronomy and least interested in topics related to physics, chemistry and botany. Girls prefer health education, medicine, and human biology on average, subjects or disciplines that are clearly of less interest to boys, who tend to like technology.

The results for England on the perceived difficulty of school science are interesting in themselves , but also highlight the care that must be taken in interpreting survey results of this kind. Other surveys, including PISA show that there may be little correlation between how students perform and their attitude to a subject. Moreover, in the case of England, complaints by students, teachers and parents that S&T subjects are more difficult than others seem to be confirmed in a study by Durham University, which calculated the relative difficulty of over 30 subjects at A-level (the final exam at secondary level) for a large sample of students in 1994 to 2003. In this analysis, chemistry and physics come out as the most difficult subjects, followed by Latin, mathematics and French. Photography, art and communication studies are the easiest.

The consequences of this can be direct – many students may decide from the outset that science and mathematics are too hard for them and do something else. Results of the PISA exercise confirm this as regards mathematics, and reveal striking gender differences too. Across OECD countries, 36 per cent of males agree or strongly agree that they are not good at mathematics, while the average for females is 47 per cent. In Italy, Japan, Korea, Norway, Poland, Portugal and Spain and Turkey, between 50 and 70 per cent of females agree or strongly agree with this statement.

2.3.3. Top students' choices

The decision to choose S&T or maths is further complicated by the weight these have in winning places in post-secondary education. Two opposite consequences are possible. In systems where subjects are weighted according to some scale of desirability or difficulty, students may choose S&T to improve their chances of admission, even if they do not intend to study these subjects later. In systems where students have to gain a certain number of points, whatever the subject, many will opt for easier disciplines to boost their scores.[13] This trend could be aggravated in systems where schools are ranked using "league tables" based on grades in national examinations: schools may attempt to dissuade students from taking

Figure 2.3. **Choice of college major by freshmen who ranked top 4% in CSAT**

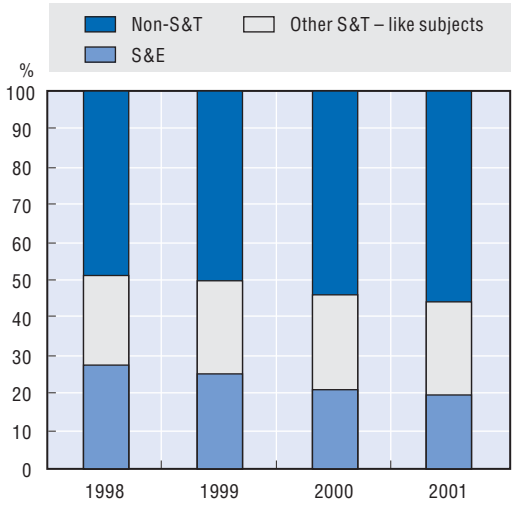


Figure 2.4. **Share of female among top 4% students**

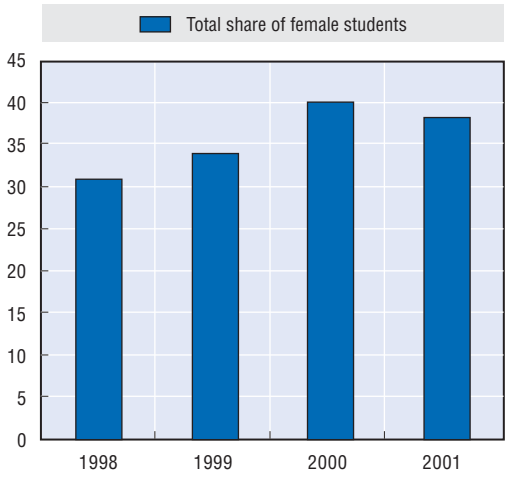


Figure 2.5. **Choice of major by male and female who ranked top 4% in CSAT**

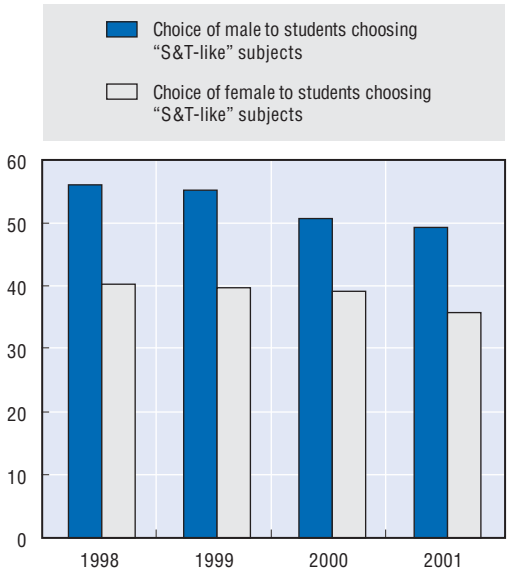
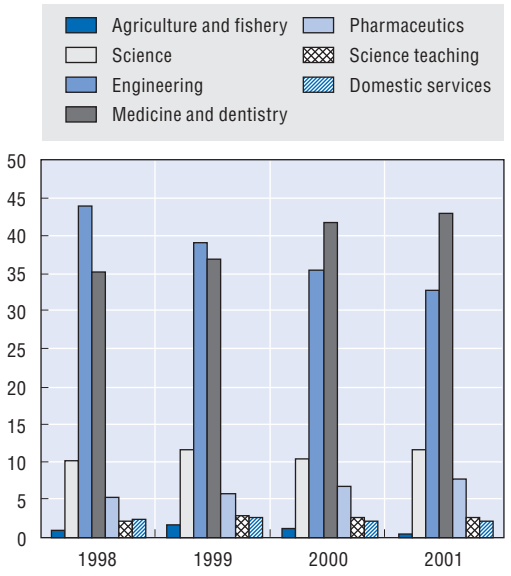


Figure 2.6. **Choice of narrow fields by freshmen who ranked top 4% in CSAT and who chose "S&T-like" major**



exams that might lower the school's score. It is thus interesting to see which subjects the best students choose, especially given the impression of many university teachers and other stakeholders that S&T subjects are becoming less attractive for these students.

Korea carried out such a study in 2002 (Mi-Sug Jin *et al*., 2002). The results show that the proportion of students who ranked in the top 4% of the CSAT (College Scholastic Aptitude Test) and who chose S&T-like subjects decreased rapidly from 51.2% to 44.1% over 1998-2001.

Some of the explanation may be linked to gender, and the contrasting phenomena noted elsewhere in this study, whereby the increase in females' overall level of

achievement is not reflected in S&T. In Korea, the female ratio increased very quickly among the top 4% of CSAT, from 30.9% in 1998 to 38.2% in 2001.

Females who chose S&T subjects declined from 40.4% in 1998 to 35.8% in 2001, while for males the decline was from 56.1% to 49.2%.

Therefore, it may be argued that the fast decrease in the share of S&T subjects among top students was partly caused by the increase in the number of excellent female students who preferred other disciplines Among excellent students who choose S&T subjects, the ratio of those choosing science and engineering as their major decreased from 53.9% to 44.2%. This shift occurred in favour of medicine, dentistry and pharmaceutics, subjects that lead to high income professions.

2.3.4. What young people say about S&T education

The Korean findings reinforce the argument that competition from other subjects can affect S&T in numerous ways. Subjects which are seen as more fashionable, exciting, relevant to modern life or offering better career prospects can attract students away from S&T, especially in systems that encourage students to take a broad range of subjects. England provides a dramatic illustration of this. Following the introduction of a wider number of A-level subjects, the number of students taking a traditional mix of science subjects (*e.g.* mathematics, physics and chemistry or biology) in 2005 was only 60% of that recorded four years earlier.

Box 2.5. **National Survey conducted by Korea Science Foundation, 2003**

Around 1 670 000 students answered the survey (9 000 000 primary, 450 000 lower secondary and 240 000 upper secondary students) about 22% of the cohort.

About a third of the students in both primary and secondary education choose maths and science as their favourite subjects. The rates were 31.5% for primary, 30.8% for lower secondary, and 35.9% for upper secondary school students.

To the question why students like maths and science classes, those who pick them as their favourites indicate as the major reason that the subjects are interesting (45.7% for primary, 62.3% for lower secondary, and 72.1% for upper secondary school students). Other reasons were that they are easy to understand, or that they get high grades, or that teaching methods are interesting.

Another third of the students choose math and science as their most disliked subjects (26.1% for primary, 28.3% for lower secondary, and 36.8% for upper secondary school students).

The main reason given for this dislike is that the subjects are difficult to understand (51.9% for primary, 57.3% for lower secondary, and 56% for upper secondary school students). Other reasons were that the subjects are not interesting, or that they get low grades, or that teaching methods are not interesting.

To the question whether the students were satisfied with the current science classes, 55.7% of primary, 45.1% of lower secondary, and 31.5% of upper secondary school students answered yes. Significantly, the satisfaction rate diminishes rapidly as students progress to higher levels of education. To improve maths and science classes, 72 to 80% of all students suggested promoting hands-on experiments and easy-to-understand curricula, with almost equal votes.

Typologies of student interest

The ROSE results have been used in some countries to derive typologies of students according to their attitude to studying science at school. In Japan, the specific preference of students for science as such ("School science is interesting") was crossed with preference relative to other subjects ("I like school science better than other subjects") to produce four groups of students (Ogawa and Shimode, forthcoming):

1. Specific Priority: showing positive attitudes toward school science from both absolute and relative preference perspectives.
2. Other Priority: showing positive attitudes toward school science from an absolute preference perspective, but negative attitudes from a relative preference perspective.
3. Poor Priority: showing negative attitudes from both absolute and relative perspectives.
4. Not-Positive Priority: showing negative absolute preference but positive relative preference.

Group 4 seems like an anomaly: students who have no interest in science, but like it more than other subjects. This might be because these students enjoy the "entertainment element" of doing experiments and playing with scientific apparatus.

Camilla Schreiner (2005) one of the organisers of ROSE devised a typology based on results for Norway. Attitudes to school generally and work are included in the typology, but only the science aspects are described here:

1. Unselective enthusiast. School science is interesting, useful and not too difficult, but no more interesting than other subjects.
2. Unselective reluctant. The opposite of the previous group, has negative attitudes towards school science and science in general, but would be negative about other subjects too.
3. Unselective undecided. Science classes are not useful, not easy, but not useless or difficult either, and has no clear stance on issues.
4. Selective girl. School science is somewhat difficult, and not very interesting. She prefers other subjects and the chances she would be interested in science later are negligible.
5. Selective boy. School science is not very difficult, and is interesting, but it's not his favourite subject. He likes technology and tools.

Box 2.6. **Young people's opinions**

According to Eurobarometer results, to the question "what do you think is the main reason – if there is one – for the falling interest of young people in scientific studies and careers?" about 60% of respondents answered "science lessons at school are not appealing enough" among their three first three answers and 55% put "scientific subjects are too difficult" among their first three.

In a Korean survey on primary and secondary education, mathematics and science are both the favourite and the most disliked subjects among students, scoring an around a third of students at each extreme. Students who pick mathematics and science classes as their favourites say the main reason is that these subjects are "interesting". Students who most dislike mathematics and science classes indicate give difficulties in understanding as the prime reason.

Students' satisfaction with the science classes is relatively high in primary education, but gets lower as the education stage goes higher. As a way to improve this, most students demand more hands-on experiments and an easy-to-understand curriculum.

The second group in the Japanese study is particularly interesting. These students like science but like other subjects even more. In some ways members of this group are similar to the first Norwegian group, who like all their subjects, but have no special reason to choose science. This suggests that it may be possible to identify and change things that science teaching is getting wrong, and learn from things that other subjects are doing more successfully to transform these pupils' positive attitudes into making science a specific priority.

The students' voice

One place to start is by asking students what they think about science teaching. This might seem obvious, but as Edgar Jenkins (2006) points out, the word "student" does not appear in the index of the two-volume *International Handbook of Science Education*, published in 1998. yet the decision to continue with S&T is bound to be influenced by the quality of teaching and the quality of advice students receive. A common thread running through criticisms of how science is taught could be summarised by saying that in many cases, the main objective is not to teach science, but how to pass a science exam. Thus instead of being introduced to the scientific method and the deductive reasoning, cooperative working and problem-solving skills it entails, students are expected to learn a number of facts by heart and be capable of reproducing them.

Overloaded curricula leave little time for discussion, and the need to ensure that students have covered all the principles and formulae that may be set in exam questions means that students may have no idea of how exciting, uncertain and sometimes even heroic scientific endeavours can be. This situation is made worse when the latest advances of science are reduced to a set of even more facts to be learned in an already overcrowded schedule. The impression of a disembodied exercise divorced from real life is also reinforced if the technology examples used as illustrations concern goods, techniques or processes that mean nothing to most students, such as blast furnaces, while high-tech objects they are familiar with such as mobile phones or MP3 players are never mentioned. This may be one reason why life sciences fare better than others – the direct link to the students is obvious, as is the connection to their wider concerns such as the environment.

A study of Finnish ninth-grade students (Lavonen *et al*., 2005) revealed that 30% would like to reduce the amount of teacher-led studying. Nearly 40% of the students would like to have more practical work or small-group projects. About 30% would like to have less studying of the textbook, and 47% of them would like to use more reference books or newspapers in classes. The students would like to see a greater variety of graphic presentation methods in teaching. Consistent with the experience of many teachers, girls chose teacher-led approaches more often than boys.

Despite the significant minority who would like to reduce teacher-led studying, students generally like the idea that new concepts are introduced by the teacher, who first presents new information and then demonstrates how this information is used for solving problems or performing tasks. In particular, the students wish that there were more teacher-led discussions in science classes. This finding is similar to that of Bahar (2003), suggesting that discussion is an important motivator of students to study science.

Students wish most of all to increase the number of visits to places of interest and the use of experts in teaching. Guest speakers and educational visits provide a starting point

that is more natural than traditional learning materials for becoming acquainted with the applications of scientific information, and show the applications of science beyond school. It is interesting to contrast the desire to meet experts with the lack of interest in the lives of famous scientists revealed in numerous ROSE surveys, suggesting that the more a topic is seen as relevant to "real" people, the more students will be interested in it.

Students would also like to increase the use of teaching methods that develop skills for both critical and creative thinking, such as debates or brainstorming, echoing calls elsewhere for the development of soft skills. This is also in line with the findings of a survey of 14-19 year-olds (Planet Science, 2004) in which over two-thirds of those who replied thought that controversial issues should be included in school science courses and most of the others didn't mind. Almost 60% thought that discussions about philosophy and ethics (such as animal testing) would make their school science education more interesting, although 15% were opposed and 28% didn't mind. Interestingly, students distinguished between what was useful and what was fun. For example only 15% described taking notes as enjoyable, but three times as many found it useful. In contrast, 75% found looking at videos enjoyable, but only 27% found it useful. These opinions may be shaped by the fact that 85% of the students considered that science teaching was exam-led, so they would find activities that improved their chances of passing more useful than others.

Investigations of what secondary students think about S&T and how they learn in school lead to a number of conclusions that seem to hold across different countries. The most discouraging is perhaps that interest declines steadily throughout schooling. This is confirmed by one of the few longtitudinal studies of the subject, which followed a group of Australian students starting in upper primary in 1980 through to 1997 (Dawson, 2000). Studies in non-OECD countries show this too, *e.g.* one by the Indian National Council of Applied Economic Research that found that while around two-thirds of 11-14 year-olds were satisfied with their school science courses, this dropped to 40% for those aged 16-18 (Ioste Newsletter, 2005). Other persistent findings are that biology is the most popular subject, physics the least and girls in all the countries surveyed are much more likely than boys to want to work with people.

Beyond the extremely useful data they supply, the various studies mentioned here also provide a number of more subjective insights. For instance, it seems that students do not think of S&T subjects in terms of definable, consistent categories. The ROSE surveys, for example, roughly follow the kinds of categorisation familiar to both curriculum designers and S&T professionals (physics, chemistry, biology…) but it is practically impossible to detect coherent patterns within these categories for students responses – they may be extremely negative about one aspect of a given discipline, and positive about another.

Choice process

Secondary S&T education faces challenging demands: provide a basic general knowledge of S&T (and develop a curiosity/inquiry-based methodology), and transmit the necessary knowledge and information to future S&T professionals (and select them).

As students are, in most countries, invited to make their first choice of future study and career path at the age of 15, in the middle of the secondary education, the challenge is to find the right balance to raise interest without giving up the necessary building of a corpus of knowledge and the selection of future scientists. Some authors suggest that

selection and specific education for future scientists should be postponed until upper secondary school and that before this stage, the only aim should be the general one. Indeed, students will, at this stage, make their choice based on a few criteria developed previously: interest, relevance to things they care for, intrinsic difficulty and rewards, and any information they have on career opportunities. Theory-oriented content, heavy workloads, selective grade systems, emphasis on learning raw facts and solving basic exercises rather than on deductive skills, problem solving and cooperative working, all tend to push those students that may not feel confident enough towards other, new subjects that are now available in many higher secondary education curricula.

2.3.5. The transition to tertiary level

In some countries, the transition from secondary to tertiary level is harder in S&T than in other subjects because of the gap between what students have learned and what is expected of them in the new context, so many students have to take remedial courses before starting the full curriculum. This gap could be one of the causes of high drop out rates. Surveys of what students find hard in S&T suggest that it is less the intrinsic difficulty of the subject matter than the way the subjects are taught and assessed (Tobias, 1993; Seymour and Hewitt, 1997; Annex B):

The most common criticisms can be summarised as follows:

- Absence of sense of community, too much competition, no debate or discussion possible.
- The missing overview. During most of the learning process, the ultimate goal is not clear.
- The tyranny of technique. Students choose science because they want to explore how the world works, and expect science to stimulate and respond to this curiosity. They are then disappointed to find that most of their time is devoted to problem solving, with little or no debate and discussion.
- Examinations and narrow skills testing. Even when teachers introduce the concepts and more general background into their courses (*e.g.* the history of an idea) what counts in the exam is getting the numerical solution right.
- Language. Each discipline develops certain ways of expressing itself. For teachers, this language is natural, they use it all the time in their work, but this is not the case for students, who have to translate the formulas and expressions particular to the field into language they can understand and then translate them back again to be able to use them in their studies.
- Excessive pace. High-achieving non-science postgraduates in one study cited excessive pace and the representation of science as rigid and uncreative as the main contributions to making science a hard subject (Tobias, 1993).
- Over-specialisation. S&T studies are considered by young people as narrow subjects, whereas many consider subjects that include a larger range of fields as more fulfilling. Also, in a fast evolving world, in which the future seems mostly unpredictable, some young people may be more secure with a larger spectrum of competences and fields of knowledge. When asked how they chose their courses at university, Belgian students answered that they did it first on the basis of their interest in the subjects and second on the basis of a desire to take a large variety of subjects and to avoid over-specialisation (Newtonia).

Some female students and students from minorities also complain about a kind of subtle discrimination, what one researcher described as "not looking like a scientist", *i.e.* not being recognised for their science potential, because they did not match cultural assumptions about who does science and what scientists do (Johnson, 2006).

2.3.6. Selection and drop-out rate

In many countries, S&T are among the disciplines where the dropout rates are the highest. Science suffers more than technology, especially maths, physics and chemistry. In Germany, for example, only 45% of entrants in physics and 42% of entrants in chemistry finish their studies in the chosen field, compared with the general average of 61% (Heublein, Schmelzer, Sommer, 2005.) In France, only 40% of students complete the two-year DEUG diploma within the allotted two years (although after repeating a year the success rate rises to 70%). Such high dropout rates have two main consequences: they mechanically reduce the production of S&T graduates; and discourage students from taking S&T studies. This is known as "Success expectancy": knowing that the success rate is low, young people tend to choose other studies.

One of the reasons for such dropout rates in some countries could be the massive expansion of tertiary education in recent decades. Particularly where there are no barriers to entry, many students may choose S&T without having the necessary level to pursue these studies successfully. This is far less likely to happen where access to S&T is reserved for the more academically gifted, or where serious efforts are made to orient students towards the most suitable studies both by teachers and counsellors at secondary school and by their opposite numbers when the student arrives at university.

In addition to a "passive" phenomenon of high drop-out rates, some institutions operate an active "weed-out" process to select the most able students over the first few years. This phenomenon may be more prevalent in S&T than in other subjects and would have a double impact. First, those who fail may disseminate a negative image of science. Second, the selection may over-emphasise abilities such as self-confidence and resistance to pressure rather than cognitive abilities. There could be a gender dimension to this. Performing with credit in the absence of encouragement, in gradually intensifying silence, is, according to Seymour and Hewitt (1997), a skill associated with masculinity and a common interaction between science professors and students, *i.e.* the professor poses a problem and then gives no guidance to the student about how to tackle it.

A further factor is that often it is hard to change tracks after a certain point in high school and many students may exclude themselves from S&T studies at tertiary level because of choices made at lower levels. Sweden created the SciTech Basic Year in 1992 to address this issue. Students who have completed studies in other fields can study for a supplementary year with a focus on S&T. The choice of courses to be taken by students is adapted to their previous knowledge, and many students do not in fact need the full year to catch up. The SciTech year at a specific university is generally attached to a place in a programme in that university afterwards, but does not count as part of the first year credits for a diploma. Every year around 7 000 students from the social science programme or from different vocational programmes in upper secondary school benefit from the SciTech Basic Year. Most of them then go on to study S&T at tertiary level, and around half are female students. The programme has also helped teacher recruitment, with about a third of students in S&T teacher training programmes for lower secondary schools coming from the SciTech Basic year.

2.3.7. The need for more professional/soft skills

Very early in their career, S&T professionals experience the need for competences other than purely theoretical/technical ones. They will have to communicate, manage projects and planning, work in teams, supervise others' work, look for money to carry out research, and so on. In many cases, S&T curricula do not include activities designed to build such skills, particularly S&T studies taught in a traditional way such as physics, mathematics or chemistry, whereas more contemporary ones do. This mismatch between what is taught and what is actually needed does not just concern "soft" skills. In Germany, engineering studies at university have been criticized because the learning of sheer facts is predominant, while the basic context of knowledge, *e.g.* for problem solving, remains underexposed. Social and key competences seem to play only a minor role in engineering studies. Students who evaluate social skills and key competences as important for working in a modern economy may be discouraged from pursuing engineering studies, especially women (Bargel, Ramm, Multrus (2001), Minks, 2000, 2004.)

2.3.8. Employment prospects

The demand in the labour market for highly qualified S&T graduates is likely to continue to grow, but paradoxically, many students may be discouraged from choosing S&T or continuing to higher diplomas because they are dissatisfied with the job prospects and career structure. Students may therefore opt for courses that allow a quicker entry into the labour market, and without the years of relatively low paid employment further studies imply. Tertiary education in S&T could thus be gradually evolving away from a more theoretical basis designed to prepare students to become researchers, to a more practical, vocationally oriented approach that is more suited to the majority of jobs students are likely to do on graduating.

Teacher motivation, training, qualifications and development

The influence of teachers on future study and career choices of pupils is always cited as very important, particularly at primary and secondary level. In addition to transmitting knowledge, teachers provide career advice (explicitly or implicitly), and are themselves role models.

Teachers' initial and further training, as well as their intrinsic motivation to teach, have an impact on teaching quality, but also on the motivational factors that influence student attitudes to science and technology studies. However, teachers frequently report that they lack the resources and opportunities to reflect upon their way of teaching and to increase their knowledge. In some countries, there are concerns about the fact it is increasingly difficult to recruit teachers in S&T.

2.4.1. Primary and secondary teachers' background

Although science is obligatory in primary school, most primary teachers have an initial non-S&T background (TIMSS, 2003). In addition, many trainee primary teachers are not obliged to take science courses as part of their training. Teachers who have avoided science when given the choice as a trainee are unlikely to feel at ease with the subject in the classroom. According to Harlen (1997) what emerges from such lack of training is a

series of strategies that teachers use to cope with low confidence in their ability to teach science. These include:

1. Avoidance – teaching as little of the subject as possible.
2. Keeping to topics where confidence is greater – usually meaning more biology than physical sciences.
3. Stressing process outcomes rather than conceptual development outcomes.
4. Relying on the book, or prescriptive work cards which give pupils step-by-step instructions.
5. Emphasising expository teaching and underplaying questioning and discussion.
6. Avoiding all but the simplest practical work and any equipment that can go wrong.

Increasing teachers' own understanding of the strategies that will encourage children' interest and ability to learn is a key factor in improving the quality of teaching and learning science. This will help to meet the criticism that science classes are confined to learning by heart a series of facts that are unconnected to each other and of little relevance to the real world. It is totally unrealistic to expect a teacher to be able to answer all the questions that children's curiosity will provoke, but if teachers understand the scientific method, know how and where to look for answers, and do not feel that their authority and status are threatened by questions they cannot answer immediately, this curiosity can become an ally in fostering enthusiasm for S&T subjects and skill in formulating problems and investigating them.

These principles apply at secondary level too. Teachers at this level have a science degree, but they still need training to keep abreast of the latest developments in their subject and in teaching methods. They may also need special training if they are asked to teach a subject other than that they studied at university. For example, 56% of those studying physical sciences in secondary education and 27% of those studying mathematics are educated by teachers who do not have any formal qualification in these subjects (*STI Outlook, 2004*).

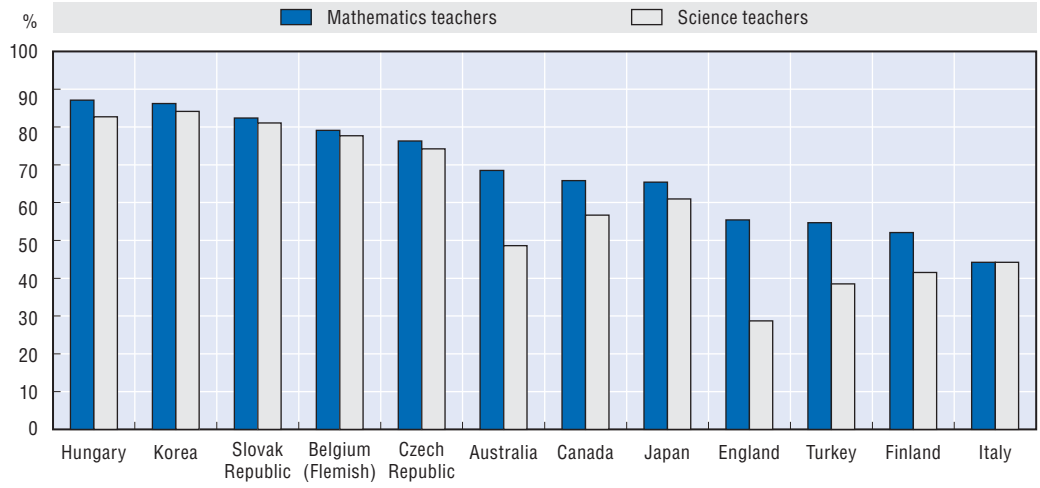
2.4.2. Teachers' motivation

Although scientists and science teachers rarely quote salary as a motive for taking up their profession, teachers inevitably compare their compensation with what is happening in the rest of the economy. Apart from the strictly financial indications, this also gives some idea of the social status of the profession, or at least of the monetary value society attributes to it. Teachers' salaries rose in real terms over 1996-2004 in virtually all countries, with the largest increases in Finland, Hungary and Mexico and in starting salaries in Australia. Salaries at the primary and upper secondary levels in Spain fell in real terms over the same period, although they remained above the OECD average level.

The annual statutory salaries of lower secondary teachers with 15 years of experience range from $10 500 in Poland to over $51 000 in Germany, Korea and Switzerland and exceed $88 000 in Luxembourg.

Pay is important in recruiting, motivating and retaining teachers in the education system, but it is only one of a number of factors that interact to determine the quality of teaching. In this respect, it is interesting to look at the percentage of 8th grade mathematics and science teachers who stated that teaching was their first choice of career when starting tertiary studies and also to see how many S&T teachers would leave the profession given the chance. In general, teaching tends to be a first choice more in

Figure 2.7. **Maths and science teaching as first choice of career**



Note: Countries are ranked in descending order of the percentage of 8th grade mathematics teachers who stated that teaching was their first choice as a career when beginning university.

Source: Trends in International Mathematics and Science Study, TIMSS, 1999.

mathematics than in science, but with considerable differences among countries. In Hungary, over 80% of mathematics and science teachers said this was their first choice of career, compared with under 30% in England.

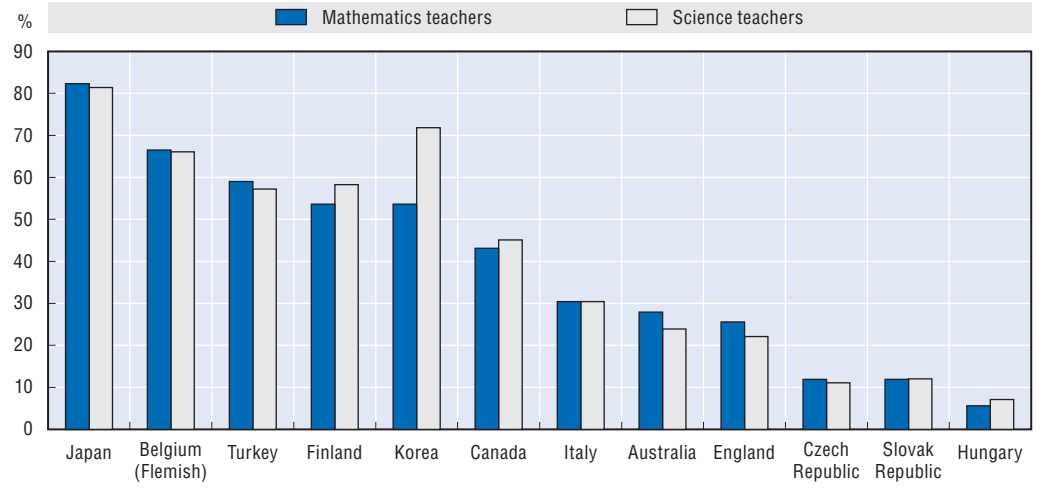
As might be expected from the previous chart, science teachers are more likely to say they would change professions than mathematics teachers, but the differences between the two groups are much less marked than for first choice of career.

Comparing teachers' views of their position in society with results for first choice of career shows mixed results. Teaching science and mathematics as a first choice does not always coincide with how teachers think they are valued by society, and in some countries there is even a negative correlation. In Hungary, for instance, almost all the respondents said teaching was their first choice of career, but practically none of them feels that society appreciates their work. Likewise for the Czech and Slovak Republics, although teachers here have a slightly more positive feeling of how their work is viewed by society than their Hungarian colleagues.

2.4.3. Teacher (in-service) training

The overall impression is that a number of factors need to be addressed to recruit and retain teachers who will encourage children's interest in S&T. Many of these are identical whether for science and technology teachers or teachers generally, such as relations with students and colleagues and good working conditions. However, the special nature of S&T poses specific challenges regarding the development of teachers' knowledge and skills. Students are attracted to these disciplines by a desire to explore and understand questions that evolve rapidly, and their motivation and competency as teachers will suffer if they lose touch with developments in their field. As mentioned above, a majority of those studying physical sciences in secondary education and over a quarter of those studying mathematics are educated by teachers who do not have any formal qualification in these subjects. Even qualified, experienced teachers may have insufficient knowledge of developments in such a fast-moving domain. Continuous training is often lacking or does not focus on theoretical subject content. As a result, many S&T teachers may need

Figure 2.8. **Society's view of teachers**



Note: Countries are ranked in descending order of the percentage of 8th grade mathematics teachers who believe society appreciates their work. The figures reflect the percentage of teachers who reported "yes" to the question "Do you think that society appreciates your work?".

Source: Trends in International Mathematics and Science Study, TIMSS, 1999.

knowledge updating and may not be at ease with the latest S&T developments. And yet, the latest S&T developments are precisely what interest most young people.

A number of initiatives address this issue. The April 2007 Science and Math Scholarship Act establishes a teacher education program at the US National Science Foundation (NSF) to encourage mathematics, science, and engineering faculty to work with education faculty to improve the education of mathematics and science teachers and to provide scholarships to students in science, technology, engineering, and mathematics (S&T) fields who commit to becoming mathematics and science teachers at elementary and secondary schools. It authorises summer teacher training institutes at NSF and DOE to improve the content knowledge and pedagogical skills of in-service mathematics and science teachers, including preparing them to teach challenging courses in science and mathematics such as the Advanced Placement and International Baccalaureate courses. It also requires the NSF to include support for master's degree programmes for in-service mathematics and science teachers within the NSF Math and Science Partnerships and authorises funding for the NSF S&T Talent Expansion program, which is expanded to include centres for improving undergraduate S&T education. A laboratory science pilot project at NSF is also established.

In March 2006, Europe's first international, multi-disciplinary (biology, physics and chemistry, mathematics, earth sciences, engineering and medicine) journal for science teaching, *Science in School*, was launched. Published by EIROforum, a partnership between Europe's seven largest intergovernmental research organisations, the journal features news about the latest scientific discoveries, current science topics, teaching materials, projects in science education, interviews with inspiring teachers and scientists, reviews of books, films and Web sites, events for teachers and many other resources for science teachers. The journal is freely available online (*www.scienceinschool.org*) and over 30 000 print copies are distributed across Europe at no cost to the recipients. It is printed in English, but online articles are provided in many European languages.

Box 2.7. **Radboud University's actions to improve teaching**

Radboud University (Nijmegen, the Netherlands) has introduced a tutor system to improve the interface between secondary and higher education. The tutors are experienced pre-university secondary school teachers who coach the students during their first year at university. They attend lectures and provide feedback to the lecturers about their teaching methods and the extent to which the material discussed in the lecture connects to what the students have learnt before. The system is considered useful by almost all the parties involved, and a trend study indicates that the interface between secondary and university education has improved considerably since the introduction of the system, and that students' perceptions of their studies has improved.

At the same time, in order to attract potential students with broader scientific interests, the university also offers new, trans-disciplinary courses: general natural sciences, molecular life sciences, information science and environmental sciences. Science studies are grouped into clusters to combat the pronounced compartmentalisation of the various courses. The bachelor-masters structure was introduced for all studies. This structure consists of a broad three-year bachelors cycle, followed by a two-year specialised masters cycle. The master offers three specialisation profiles: research, communication/education, and management. Science students are enthusiastic about these changes, which correspond better to the interests of first-year students, and allow students to transfer more efficiently to another course within the faculty.

New teaching methods and objectives were introduced to emphasise the acquisition of general skills such as communication and cooperation and the ability to deal with large quantities of information and its application. Teaching material is offered increasingly in a project-oriented and context-linked manner. The majority of the science students are enthusiastic about the new methods and faculty have developed a greater educational awareness. However, effecting the cultural switch aspired to by the faculty board, turned out to be a laborious process. Radboud's experience suggests that it is better to implement these changes in a process-oriented manner, making it possible to prioritise matters. Success requires developing specific human resource management capacities in which more attention is paid to the didactic qualities of new employees/professors, and the division between research and teaching tasks should be clear.

2.4.4. Tertiary teachers

S&T teaching staff are often recruited among high-level researchers and on the basis of their technical competences in their specific subject. In many countries, this does not include any requirement or training in how to teach. As mathematics and S&T subjects are notoriously perceived as difficult by students, such lack of pedagogic skills may have some influence in the often high drop-out rates observed among students in the first two years of higher education.

In many countries, tertiary education teachers do not only teach but are involved in research, consulting and management activities. In some cases, teaching can be considered as not of primary importance for them, especially in countries in which their assessment and career path rely mostly on research activities, and when the rewards (financial or career-wise) offered to S&T tertiary teaching are not attractive enough compared with other aspects of the job. This may result in under motivation and difficulties in recruiting. This sentiment could be reinforced by university league tables that rank establishments according to research performance. As higher education

institutions become more market oriented, there is a danger that attracting students becomes an end in itself, and "retention" becomes the dominating standard by which to judge performance, *i.e.*, how many students stay all the way through their course. There could emerge a paradoxical situation where in the most "successful" universities, teaching and academic standards are poor, but students are attracted because they have a good reputation for research (on which "league tables" are based) and in ensuring that you get your degree.

Gender and diversity

Female students are the most obvious resource for increasing S&T enrolments. In some respects, this is also true for young people coming from some minority groups in OECD countries, and the factors that affect their choice or success in these disciplines overlap. However, these issues are difficult to act upon, as a number of complex interactions are involved, including social and economic factors.

Many surveys have shown clear differences between boys and girls in their experience with, interest in, and attitudes to science and engineering, so it is not surprising to see these attitudes transposed into differences in their choice of studies. Furthermore, girls tend to show a stronger interest in people rather than facts or "things", and these differences are amplified in the way S&T are taught, and in the perception of S&T careers. These differences do not appear to be related to ability, since girls tend to succeed well in S&T, especially in the early stages. Some experts are working on the re-engineering of the education process to offer equal opportunity to both genders, but no consensus has yet emerged concerning the assumptions, methods, or results that can be achieved.

Some minority students are poorly represented in S&T studies, although detailed analyses are missing for many countries. The low rate of pursuit and high dropout rate is a concern in several OECD countries, although socio-economic considerations, as well as differences in cultural and environment factors, make for complex and difficult analyses and solutions.

In many respects, women and minorities present similarities in the factors that may lead them to refrain from choosing S&T related studies and in the factors that may affect their success in these disciplines. For this reason we decided to cover both categories together where this seemed appropriate, but bearing in mind that in many instances there is no overlap between the two.

2.5.1. Gender

Despite recurrently fashionable talk about "male" and "female" brains, there is absolutely no scientific evidence of a biological difference that would account for the lower number of females studying S&T or achieving professional success in these fields, the more so since the situation, although generally to the disadvantage of women and girls, varies from one country to another and one discipline to another. Moreover, gender differences in educational success generally are increasingly to the advantage of females and where they are not, women from the younger generations are rapidly closing the gap.

Primary and secondary levels

The decision to continue with S&T at a higher level of education (and to choose this as a career) is strongly influenced by experience at earlier levels of schooling, and indeed in

most cases depends on achieving a certain level in mathematics and science in primary and especially secondary school. At around age 15, secondary school students often start to choose their future path, or have it chosen for them. In this respect the 2003 PISA exercise is especially enlightening for the purposes of this part of the study since in examining performance in mathematics, it included gender differences. The results show that boys slightly outperformed girls in most OECD countries except Iceland, mainly because more boys performed at the highest level. At the lowest performance levels, scores for boys and girls are similar. In Australia, Austria, Belgium, Japan, the Netherlands, Norway and Poland, gender differences are not statistically significant for the tests overall. In the other countries that took part, sometimes boys did better than girls in all the areas tested, sometimes in only some of them. In any case, the differences are too small to explain the diverging educational and career pathways observed later in life (and in science, gender differences in performance tend to be smaller still).

Although TIMSS and PISA both show a widening gender gap over time, the gender differences in science and mathematics performance are small compared with the choice of subjects in further education. Large gender differences are found however in more subjective aspects of learning, such as how much students enjoy a given subject, how confident they are of their ability to do well in it, how stressed they are by it, etc. These factors are important in determining which subjects secondary school students will go on to study at higher levels, and the PISA data show important gender differences that underline the importance of schools in shaping future preferences for S&T subjects.

As well as performance, PISA examined interest in and enjoyment of mathematics, motivation and self-concept. Gender differences regarding interest and enjoyment are much more marked than performance, with 37% of males on average across OECD countries agreeing or strongly agreeing with the statement that they enjoy reading about mathematics, compared with 25% of females. These findings are based on students' own subjective assessments, and given the large cultural and other differences across countries, they need to be interpreted with extreme caution when seeking to make international comparisons.

Choice of future studies and profession is influenced by whether students think they have the ability to succeed. In general, students are less confident in their ability concerning mathematics than reading, and females are generally much less confident in mathematics than males. On average across OECD countries, 36% of males agree or strongly agree that they are simply not good at mathematics and 47% of females. In Italy, Japan, Korea, Norway, Poland, Portugal, Spain and Turkey, the figure rises to between 50 and 70% of females. There is a moderately strong association between individual students' performance and their self-concept in mathematics, but the data suggest that schools in which students tend to have a strong self-concept in mathematics also tend to have high levels of performance.

Given that female students appear less confident in their mathematical ability, it is no surprise that they also express high levels of anxiety and stress concerning mathematics. Half of the 15-year-old males and more than 60% of females in PISA 2003 report that they often worry that they will find mathematics classes difficult and that they will get poor marks. On the other hand, despite these worries, fewer than 30% of students say that they get very nervous doing mathematics problems, get very tense when they have to do mathematics homework or feel helpless when doing a mathematics problem.

Although it could be argued that some stress is inevitably associated with subjects seen as important, and that it can sometimes be helpful in motivating students, PISA data

indicate that anxiety is negatively related to performance. A one-point increase on the PISA index of anxiety in mathematics corresponds, on average across OECD countries, to a 35-point drop in the mathematics score, which is just over half a proficiency level. This negative association remains even if other learner characteristics such as students' interest in and enjoyment of mathematics are accounted for.

Social conditioning in and out of school

The data presented above go some way to explaining, or at least exposing, gender differences, but they need to be completed by a more general look at how society influences outcomes, and why females choose S&T less often despite their superior performance on many indicators. One reason could be that parents' wishes and expectations regarding education and careers are lower for girls generally, and even more so in S&T. When a boy fails in S&T, parents tend to choose to have him repeat the year but not to drop S&T, while for a girl the choice is more often to change from S&T to another subject (Duru-Bellat, 2004; Alaluf, 2004). This could be reinforced by a phenomenon noted by certain observers whereby females find it easier to give themselves permission to reject a conventional, materially-focused career path in favour of one based on intrinsic interest, self-development, altruism, or the need for social interaction (Seymour and Hewitt, 1997).

Some researchers have found that within the family, it is generally the father who impacts his daughter's attitude to S&T by encouraging and approving her interest in these questions. (Engler and Faulstich-Wieland, 1995, quoted in *Les maths et les sciences n'ont-elles plus la cote?*).[14] If this is the case, one might expect that the increase in family break-ups and the number of families where the father is absent most of the time would have an impact, but this is outside the scope of the present study.

Teachers, as part of society, respond to mainly the same stereotypes as in the general population. Their evaluation of students' performances differs strongly between boys and girls. Where a boy's achievement is attributed to ability and skills, girls' achievement tends to be seen as the result of hard work and perseverance.[15] Studies have also shown that in some maths contexts, teachers tend to devote more time and individual attention to boys (Duru-Bellat, 2004).

Several studies have shown that girls tend to comply with the gender stereotypes more strongly in presence of boys,[16] leading to several programmes of S&T classes for girls only. At secondary level, for example, when taught separately, girls seem to be more prone to make choices against stereotypes and express interest in physics or technology.[17] The causes for this pattern are multiple:

- Physics and maths being considered as masculine, girls may choose not to do these subjects in order to be considered as feminine by their male colleagues.[18]
- Teachers who split up their group into "boys" and "girls" and use this artificial opposition as a pedagogical tool. This could lead to artificially emphasising gender stereotypes.
- What is generally called "expectation effect": some studies show that science teachers tend to demonstrate more attention and encouragement to boys and act towards them according to stereotyped expectations. This would have an impact on students' self-confidence.[19]
- The gender stereotyped image of discipline may be reinforced by school textbooks.[20]
- Teachers may lack specific skills and knowledge on the way to teach S&T to girls.

Some studies suggest that a same sex context would provide girls with the opportunity to consider themselves more as individuals than as the members of a defined sexual group and they would then be more easily able to choose study disciplines traditionally considered as masculine.

Whatever the reasons, there is obviously a problem with how science is perceived. The percentage of girls who say that the sort of science done in schools makes them less likely to go for a job in S&T rises from 34% in year 7 to 83% in year 11 (Woolnough, *Changing pupils attitudes to careers in Science*).

Out of school activities

Girls appear to have different out of school experiences than their male peers and these are less frequently oriented towards science. Significantly more boys than girls indicate that they have visited a factory, a weather station or an electric plant, for example. More boys than girls indicate that they read science articles, watch science television shows, and complete science projects (Jones and Howe, 2000).

Orientation

Teachers and counsellors have patterns in the way they give advice to students according to their gender: S&T do not belong to the pattern they have for females. This is compounded by the fact that girls tend to under-evaluate their performances in maths and S&T. This leads them to avoid these subjects as they fear they will not be able to succeed. Among the criteria that lead girls to the choice of their career, helping people is a strong positive one, and the image of S&T fits badly with this. Baker and Leary (1995) found that the girls rejected physical sciences in particular because these subjects are not viewed as helping or caring, instead preferring areas such as biology that would allow them to help people, animals, or the Earth.

In an experiment conducted in French high schools two years before the end of secondary education, fictitious orientation files with the same data were tested with teachers. When the fictitious first name is male, teachers' orientation of the student towards science is twice as frequent as when the first name is female.[21]

As a consequence, girls tend to self-censor and self-select themselves and thus renounce both selective courses and scientific courses. Moreover, as mentioned above, in case of difficulties, girls are more prone to give up and choose reorientation to their second choice courses (Vanheerswynghels, 1994, 1996.)

A male culture

A male culture in engineering and science (mainly computing and physics) puts women off these subjects. Mathematics, science and technology are generally perceived as male subjects and male stereotypes are associated with them. Since S&T subjects are traditionally male, the teaching of them has been developed in a context that is more favourable to men. Some male values may be promoted through the way S&T is taught, which can drive female students away.

2.5.2. Tertiary level

At one time, women were refused admission to tertiary level education, and not surprisingly, for many decades after they were admitted, they lagged behind men in terms of overall attainment. The situation has now been reversed in many instances, with

women outperforming men in recent cohorts of graduates. However, while women obtain more than half of all university degrees in many countries, only around 30% of university degrees awarded in science and technology are to women. Women account for only 25% to 35% of researchers in most OECD countries, with the exception of Japan and Korea (12% each). In terms of participation in careers, just over one-third of US university faculty are women, a figure that is much lower in EU countries and in Australia and Korea (14.5%). Women also make up less than 20% of senior academic staff in most EU countries.

The OECD countries face a paradoxical situation: a feminisation of the workforce in general and of university-trained graduates in particular, but continued under-representation of women in research (*STI Outlook 2006*). The problem does not suddenly emerge at tertiary level, but is recurrent from the earliest days of primary school. Fewer girls than boys take science subjects, and of those who do, more are likely to drop S&T in favour of something else.

The US National Academy of Sciences argues that, in US higher education at least, the problem is not simply the pipeline, and many of the NAS's conclusions probably apply to other countries and levels of education too. Overall, scientists and engineers who are women (or members of racial or ethnic minority groups) have had to function in environments that favour men, either deliberately or, most of the time, inadvertently. Well-qualified and highly productive women scientists have also had to contend with continuing questioning of their own abilities in science and mathematics and their commitment to an academic career. Minority-group women are subject to dual discrimination and face even more barriers to success.

Studies show that female university students tend to consider that S&T careers are not very compatible with family life (Ware and Lee, 1988). Studies show that women, even those graduating from the best schools, still tend to choose professions that will allow them to control their own working hours (Couppié *et al*.).

In countries without affirmative action policies, young women may anticipate a lower probability of success than their male peers and then refrain from taking S&T studies. The chance of obtaining a grant for post-doctoral research in some scientific fields may be weaker for women. This was for example shown by Christine Wenneras and Agnes Wold in a 1997 study for Sweden (quoted in *Les filles face aux études scientifiques*, p. 20).

2.5.3. Minorities

Society is a mosaic of social, ethnic, cultural, sexual, linguistic and many other minorities, so the same person can be a member of a minority by one criterion but the majority by another. In the present context, minority is taken to mean ethnic/racial minority, since these groups are almost always what is referred to when talking about minorities in S&T, even though some governments also include people with disabilities in programmes and studies targeting minorities. Given the future need for scientists, technicians and engineers to replace those who will retire and meet the expected extra demand for qualified personnel, it makes sense to recruit from as wide a pool as possible and this implies encouraging children from every background to study S&T. The analysis is however made more complicated by the fact that often people from ethnic minorities cumulate the disadvantages of socio-economically less-privileged backgrounds with the effect of belonging to a minority group. This makes it difficult to distinguish between the factors linked to the economic background from the ones coming from the cultural background. Some of these issues are described at the end of this section.

Box 2.8. **Some key elements about gender and S&T studies**

PISA: "It is of concern that in most countries males are statistically significantly more interested in mathematics than females and in half of the countries this difference is very substantial."[1] In most countries females feel more anxious in maths.[2] The analysis shows that students who are less anxious perform better regardless of other characteristics.[3]

TIMSS data shows that gender difference in interest in science and mathematics become larger between 4th grade and 8th grade. It suggests that gender issue should be tackled in the early stage of education.

Gender differences in students' experiences, interest and attitudes toward science and scientists.[4]

Young people and their professions: dream and reality: Girls tend to choose professions with a strong "relational" and "values related" dimension: education, arts, social and humanitarian work, health care, commerce and communication. Meanwhile, boys tend to choose professions in which they can get a specific know-how and be professionally recognized on this basis: computing/ multimedia, sport, arts, construction, industry/mechanics and economy/finance.

Osborne Attitudes towards Science: Research studies have identified a number of factors influencing attitudes towards science in general. These can be broadly defined as gender, personality, structural variables and curriculum variables. Of these the most significant is gender for, as Gardner comments, sex is probably the most significant variable related towards pupils' attitude to science. This view is supported by Schibeci's (1984) extensive review of the literature, and more recent meta-analyses of a range of research studies by Becker (1989) and Weinburgh (1995) covering the literature between 1970 and 1991. Both the latter two papers summarize numerous research studies to show that boys have a consistently more positive attitude to school science than girls, although this effect is stronger in physics than in biology.

1. PISA p. 121: "While the preceding chapter showed that differences in the mathematics performance of males and females in at least two of the four mathematics scales tend to be small or moderate, it is noteworthy that, with the exception of Iceland, Ireland, Portugal, Spain and the partner countries the Russian Federation and Thailand, males express significantly higher interest in and enjoyment of mathematics than females, and particularly so in Austria, Germany, Switzerland and the partner country Liechtenstein".
2. Finally, females experience significantly more feelings of anxiety, helplessness and stress in mathematics classes than males in 32 of 40 countries. There are statistically significantly higher levels of anxiety among females in Austria, Denmark, Finland, France, Germany, Luxembourg, the Netherlands, Norway, Spain and Switzerland, as well as in the partner countries Liechtenstein, Macao-China and Tunisia. Pisa p. 155.
3. First, the various aspects of student anxiety in mathematics closely affect performance, over and above associations with other learner characteristics. The strength of the influence is shown by the width of each arrow. The results show that students with an absence of anxiety about mathematics perform strongly in mathematics, regardless of other aspects of their attitudes or behaviour. When other factors are taken into account, students' interest in and enjoyment of mathematics have on average no clear association with performance. PISA p. 148.
4. "Beginning as early as elementary school, boys have typically possessed more interest in studying science than girls (Clarke, 1972; Clark and Nelson, 1972; 1971; Kotte, 1992). In an initial study of gender and students' science interests, Kahle examined data from the National Assessment of Educational Progress (NARP) and found that girls described their science classes as 'facts to memorise', and 'boring' (Kahle and Lakes, 1983). By middle school, girls attitudes toward science tend to decline and this decline may persist through high school (Sullins, Hernandez, Fuller, and Tashiro, 1995). Kotte (1992) reported that, for students from ten countries, the differences between males and females' attitudes toward science widens as students move from elementary to secondary school. Furthermore, Kotte reported that the sharpest increase in gender differences in attitudes takes place between the ages of 10 and 14 years. In an examination of data from 19 000 eight grade students who participated in the National Educational Longitudinal Study, Catsambis (1995) found that males were more likely to look forward to science class and to think science would be useful to their future and were less to ask questions in science classes than their female peers. Girls' less positive attitudes, according to Catsambis, existed even though they performed as well or better than boys, receiving better grades in science classes. In addition, Catsambis found that over twice as many middle school boys as girls are interested in a future career in science."

Data on ethnic minorities

Unfortunately for this study, many countries do not gather data on the ethnic background of students because it would be negatively perceived to identify people according to their ethnic origins, even if there is strong anecdotal evidence that students from these backgrounds are not as well represented in S&T studies and related occupations as their numbers would suggest. Moreover, in some OECD countries, ethnic minorities are tiny. The data used in this section therefore come from an extremely limited number of sources, mainly in the United Kingdom and the United States, but the general conclusions that can be drawn probably apply to other countries and to other situations too, such as children from working-class backgrounds or female students.

In April 2005, the UK Royal Society published a report looking at ethnic minorities in upper secondary schools, in higher education, and in science, engineering and technology (SET) occupations. The report argues that ethnic categories such as Black, White and Asian are far too broad to give meaningful information (Royal Society, 2005). For example, among Asian groups, Indian and Chinese people are over-represented in terms of access to and achievement in SET compared to the White UK population. In contrast, Bangladeshi people are under-represented, both in terms of occupations and educational attainment, and the problem is more acute among Bangladeshi women. Among the Black ethnic minority population there is a sharp contrast. While Black African people are over-represented in SET compared to the White UK population, this is not the case among Black Caribbean people, and in this instance the problem of under-representation is worse among males.

At tertiary level, the same patterns emerge, with 7.8% of the Chinese population and 5.1% of the Indian population holding SET-related degrees, compared to 3% of the White population. Again, the lowest achievers are the Bangladeshi population (1.5%) and the Black Caribbean population (1.4%). The proportion of the population having any kind of degree varies from 6% for Bangladeshis to 24% for Chinese.

Given the importance of role models, the number of Bangladeshi women in SET occupations is especially worrying: 200 in the whole of the UK (and only 700 men).

In the United States, broadly similar patterns emerge, with white men, who are about a third of the population, holding three-quarters of the jobs in S&T occupations. The data are similar to the UK figures concerning the performance of Asians, but for the other minorities, discrepancies in employment between demographic weight and share of diplomas awarded grow by level of qualification. For example, Black/African Americans make up 12.2% of the total population, but only 7.2% of Bachelor-level graduates in S&T occupations are Black, and only half this proportion in doctorate/professional level. For Whites, their demographic weight (77%) is practically the same as their shares at all levels.

On the recommendation of the Congressional Commission on the Advancement of Women in Science, Engineering, and Technology, BEST (Building Engineering and Science Talent) an initiative of the Council on Competitiveness, was established in September 2001 to promote more diversity in the US technical workforce. Several indicators suggest that US higher education is not adequately meeting the challenge of under representation, including disproportionate attrition of undergraduate students from underrepresented groups from technical majors; insufficient PhD completion rates for persons of colour, plus their low numbers in junior faculty positions at leading research universities; and persistent under representation in tenured faculty positions in the physical sciences and engineering.

The mission of BEST was to identify programs in higher education which show promise in developing talent from populations underrepresented in the science and engineering workforce. It evaluated programmes and practices using a combination of criteria covering programme definition, outcomes, longevity, and unexpected consequences. Outcome criteria cover the extension of the programmes beyond a single site and to populations different from that initially targeted. Eight design principles underpinning exemplary and promising programmes were derived:

1. Institutional leadership: commitment to inclusiveness across the campus community.
2. Targeted recruitment: investing in and executing a feeder system.
3. Engaged faculty: developing student talent as a rewarded faculty outcome.
4. Personal attention: addressing, through mentoring and tutoring, the learning needs of each student.
5. Peer support: student interaction opportunities that build support across cohorts and allegiance to institution, discipline and profession.
6. Enriched research experience outside the classroom: hands-on opportunities and summer internships that connect to the world of work.
7. Bridging to the next level: institutional relationships that help students and faculty to envision pathways to milestones and career development.
8. Continuous evaluation: ongoing monitoring of process and outcomes that guide programme adjustments to heighten impact.

The authors of the BEST report also emphasise the importance of comprehensive financial assistance for low-income students so that they can concentrate on academic work.

Although females and ethnic minorities may face some similar problems, students from ethnic minorities can also face a number of specific problems:

- Teacher attitudes. A survey in the US of over 1 000 faculty showed the belief that non-Asian minority students were less motivated, have a lower high school level, supplied with lower level of family support, have a lower level of understanding of the higher education system and poorer economic circumstances that can adversely affect their academic performance (Treisman, 1992).
- Lack of knowledge of the educational system. Minorities may be convinced about the importance of S&T-studies but meet problems because they tend to choose the wrong type of education, because their knowledge of the education system is too restricted.
- Disappointment about their comparative level. The situation for many of the "minority" students is that they come from comparatively modest high schools. In these schools, they were among the top students. Yet, at university, they compete with more selected peers and they may have to adjust to a more modest comparative status. This point is stronger in those countries in which affirmative action type programmes are in use. Even in the absence of any affirmative action policy, the geographical distribution of the population is often linked to their socio-economic situation (what the sociologists call "geographic segregation"). This, in addition to the diversity of tuition levels (state/ private high schools) results in a relative homogeneity of students in each high school (some having more socio-economically privileged students, others underprivileged students).
- Peer pressure. In some socio-economically disadvantaged minority populations, young people have so much internalised they have few chances to succeed in S&T (and other

competitive fields of study), that there may exist a kind of peer pressure against succeeding in these studies. Then, the young people that would want to invest time and heavy work to undertake such studies would be denigrated and to some cases excluded from their peer group. (Breakwell and Beardsell, 1992; Talton and Simpson, 1985).

- Risk aversion. Due to their economic and cultural context, some minority parents may have a strong aversion for risk. This is generally the case for low economic status groups and may be reinforced from being a minority. Aversion to risk generally involves taking shorter studies and choosing subjects in which the drop out rate is low, thereby discouraging nstudents from taking S&T, seen as more likely to end in failure.
- Insufficient financial resources. Insufficient financial resources to complete an SME degree has been consistently identified as a contributor to the loss of students from minority groups from S&T majors. Family responsibilities, which are more common among these students, exacerbate their financial problems. The long hours spent in paid jobs reduce their ability to fulfil the academic requirements.

Conclusions

The expression "women and minorities" is often heard in discussions about how to encourage interest in S&T studies and how to expand the pool of talent on which to draw. As a general expression about the need to fight discrimination and promote diversity, this categorisation is a useful shorthand. Some actions can indeed be applied to both sets of people (mentoring and role models for example) and negative attitudes and stereotyping may affect both groups. However, many issues demand more specific solutions. For instance, surveys suggest that social utility is an important factor in women's choice of studies, so it makes sense to work on this when designing actions to attract women to S&T.

Analysing the situation of ethnic minorities poses two additional problems: lack of data and the wide variety of outcomes across different minorities. An additional difficulty arises in separating any disadvantages linked to ethnic background from those due to other socioeconomic factors. Nonetheless, the data that do exist show that while some groups do better than the majority, notably students from Asian families, others are left behind, and women from some minorities seem to be particularly underrepresented.

A further difficulty is that efforts targeting a specific group can give some people the impression that students from the group in question are less talented than those who do not benefit from any special measures.

Gender and ethnic diversity is therefore another illustration of how S&T issues arise from and have to be treated in the wider social context. They are as much about attitudes as about opportunity. Attitudes of the students themselves, who may feel that S&T studies are beyond their abilities or ambition. But more importantly, the attitudes of the many actors who create the students' perceptions in the first place.

Notes

1. Choosing science at 16: "The decline of the traditional manufacturing base in general over the last 25 years, and more recently the fragility of even newly-established high-tech industries, was seen by teachers and particularly careers advisers as a major deterrent to contemplating careers in S&T."
2. Choosing science at 16: "The decline of the traditional manufacturing base in general over the last 25 years, and more recently the fragility of even newly-established high-tech industries, was seen by teachers and particularly careers advisers as a major deterrent to contemplating careers in S&T."

3. Alalouf 2004, "Women and scientific professions": the increase of tertiary education students was mainly nourished by female and less-privileged students.
4. Marc Romainville, 1999, p. 53 (in French) (translation: "The overall expansion of higher education is a fact (…) Young people of which none of their parents has a tertiary education diploma now accede to University. They are inevitably less informed of university custom and of first years implicit expectations").
5. Students from less-privileged economic background tend to choose short studies and to avoid risky paths (what can easily be explained on an economy point of view) and sciences studies are long and risky (due to drop out rates).
6. Zwick et Renn (2000, pp. 101-102), quoted in "Les maths et les sciences n'ont-elles plus la cote ?"; CSRE 2003, p. 89.
7. Annual Report on the Promotion of Science and Technology, FY 2003, pp. 26-27 – Japan "Science and technology have until now been contributing to enriching life and social activities. Meanwhile, the people seek in general has shifted its focus from material affluence to spiritual enrichment, and thus future science and technology will need to contribute as well to the wealth of the spirit." Results from a 2004 survey: "those who wish to focus more on spiritual enrichment now that they have achieved a certain level of material affluence": 60%; response to the question "How do you feel about the opinion that future development of science and technology should concentrate on realising not only material affluence but also on enriching the lives of people": 58.9 I think so; 21.6: I somewhat think so.
8. Rand "In the Netherlands and Italy freshmen clearly prefer law, economic and social and health sciences".
9. The "crisis of science vocations" and its causes – Observa "First of all, the idea of a welfare-bringing science, consolidated and widespread at least from the period during the two World Wars, has been increasingly put under question since the first Seventies; potential negative consequences of science and technology development – *e.g.* for health and the environment – have been increasingly emphasised. Particularly in the past decade, science issues (from BSE to biotechnologies) have frequently been subject to intense public discussion and controversy (Bauer *et al.*, 1995; Bauer and Gaskell, 2002; Bucchi and Mazzolini, 2003; Bucchi, 2004). While it cannot obviously be expected to explain the phenomenon of the 'science vocation' crisis, this shift in broad cultural framework has to be taken into account in terms of scenario."
10. Knowledge about science was measured using a series of 13 questions or statements: the centre of the Earth is very hot; all radioactivity is man-made; the oxygen we breathe comes from plants; the father's gene decides whether the baby is a boy or a girl; lasers work by focusing sound waves; electrons are smaller than atoms; antibiotics kill viruses as well as bacteria; the continents have been moving for millions of years and will continue to move in the future; human beings developed from earlier species of animals; the earliest humans lived at the same time as the dinosaurs; radioactive milk can be made safe by boiling it; does the Earth go around the Sun, or does the Sun go around the Earth? How long does it take for the Earth to go around the Sun? On average, Americans got 8.2 right, Europeans 7.8 (NSF, 2001).
11. EKOS: 86% of university researchers are trusted when they speak about issues related to science in Canada, 84% of university scientists (compared with 22% of business executives and 35% the media).
12. As an example, in France, in 2004-2005, a group of important scientists warned the government of their intention to emigrate if a solution to their problems was not to be found rapidly.
13. Of course universities may react by explicitly or unofficially favouring candidates with a more "traditional" portfolio.
14. Cockburn (1988) explains mother's relative lack of influence by the fact that they only use technology in the home, while fathers repair it, maintain it, etc.
15. Mireille Desplats, 1989; Nicole Mosconi, 1999.
16. Lorenzi-Cioldi, 1988; Durand-Delvigne and Duru-bellat, 1998.
17. Lawrie, 1992; Solnick, 1995.
18. Kelly, 1985.
19. Kimball, 1989; Crossman, 1987.
20. Crabbé *et al.*, 1985; Rignault and Richer, 1997.
21. Quoted by Françoise Vouillot, at the Symposium "Où sont les filles?".

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Chapter 3

Increasing Student Interest in S&T Studies

While young people generally have a positive view of science and technology (S&T), the image of S&T as a profession is largely negative. Positive contacts with S&T at an early age can have a long-lasting impact while negative experiences at school, due to uninteresting content or poor teaching, are often very detrimental to future choices. Teachers frequently report a lack of resources and opportunities to reflect upon their way of teaching and to increase their knowledge. In many countries, most primary teachers come from a non-S&T background, and many have not had any specific training in S&T. Interest in S&T is observed to decline most sharply around age 15. This is also when gender differentiation starts to translate into choices, and when key future orientations are set. Curricula are often too rigid to allow pupils who do not choose S&T as their primary subjects to come back to science later.

Introduction

As discussed earlier, a wide range of factors interact to shape the choice of studies and career, and efforts to increase student participation in S&T have to take into account the possibly conflicting influences of the family and social background, student expectations, the image of S&T compared with other subjects, employment prospects, and so on. Given the importance that S&T is expected to have for national competitiveness and the fears that not enough students will take up S&T studies, a number of schemes have been proposed to encourage student interest. Too often, however, these initiatives are not based on hard evidence and they do not include the evaluation processes needed to build future evidence-based knowledge. Paradoxically, actions are often based on the individual experience of science education professionals and specialists, but are little supported or sustained by scientific results or knowledge. Nonetheless, a number of useful action plans and other schemes have been formulated, and their experience and conclusions could be useful to the community of science educators in general.

Any scheme has to bear in mind that the education system has to satisfy two sometimes conflicting demands, particularly at primary and lower secondary level. The first is to pass on the basic S&T knowledge that all citizens should possess, as well as making everyone familiar with scientific thinking, and developing curiosity and interest in science. The second is to provide detailed knowledge to potential S&T professionals and ensure that there is an adequate supply of these professionals. Whereas the first demand involves a more participative approach and focuses on interest, the second involves teaching more conceptual and challenging material. The difficulty is to use an appropriate mix of both types of teaching methods and subjects – a problem that has long been at the centre of the debate about science education.

Encouraging interest in S&T involves dealing with an enormous range of parameters. The populations targeted, for example, range from very young children to experienced professionals. The policy instruments and governance structures cut across administrative, judicial, regulatory and ministerial boundaries. Furthermore the decentralised nature of higher education policy in many countries limits the scope and coverage of national policy measures. Such a policy landscape makes it extremely difficult to assess the effectiveness of individual policies and measures, many of which take place at the grassroots or institution level and whose impact (or lack thereof) may depend on the success of other measures at different levels and under the competence of different actors (*e.g.* schools, local governments, national education ministries, research funding agencies) and require time to be evaluated.

This means that ideally, interventions to improve human resources in S&T will take account of the educational system as a whole. This does not mean central planning of the entire process with little regard for lower level initiatives and concerns, but rather a

constant awareness of how actions on one aspect are influenced by, and influence in their turn, other parts of the system.

This section looks at the various levers that can be used to raise interest in S&T beyond the traditional pool of talent and describes some of the types of programmes aimed at the different actors in the chain of teaching and learning, as well as those that address future S&T professionals.

Bottom-up and top-down action plans

Success in encouraging interest in S&T will depend on some factors that are outside the scope of education and S&T policy, but major factors that determine success or failure can be shaped: the curriculum and teaching, the image of S&T, and efforts to promote diversity. Reform of S&T education has to address both theoretical and practical questions concerning how children and adults learn, what they should be taught, and how this should be taught. In order to avoid setting about this in a fragmented way, many countries have drawn up action plans, organised on a bottom-up or top-down pattern, with some overlap between the two approaches in actual implementation.

3.1.1. *Bottom-up approach*

Bottom-up plans are exemplified by the "call for proposals" type. This consists in drawing up a set of objectives, dedicating funds and letting the actors build their proposals. The main difference between the different actions plans of this kind will be on the level of specificity of the set of objectives. In the best cases, the funded projects will be followed and assessed, but often the instigators no longer have the power to act upon the implementation or to impact on the process. In some cases, a "contract of objectives" can be negotiated and formalised between the funding organisation and the project leaders. Then, the funding may be partly subordinated to achieving objectives.

Japan and Italy, for example, have launched bottom-up plans. Japan's "Science Literacy Enhancement Initiatives" has been implemented since 2002 to increase the willingness of young people to learn about S&T. The "Science Degrees Project" in Italy aims to arouse the interest of the population (and of the young in particular) in science and to combat the negative perception of science.

Box 3.1. **Bottom-up action plans**

Science Literacy Enhancement Initiatives (Japan)

www.mext.go.jp/english/org/science/54.htm.

In 2002, the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) launched the Science Literacy Enhancement Initiative, which involves comprehensive and consistent steps to improve science and technology education and foster promising scientists and engineers. The plan has four main components:

1. *Super Science High School.* MEXT designates high schools that emphasise science, technology and math education as "Super Science High Schools" (SSHs). SSHs undertake research and development of innovative curricula with emphasis on science, technology and mathematics study and effective ways of collaborating with universities and research institutes.

Box 3.1. **Bottom-up action plans** *(cont.)*

2. *Rika Daisuki School*. MEXT defines areas where certain elementary and lower high schools are designated as "Rika Daisuki School" (model schools for the promotion of science education). In Rika Daisuki Schools, education with emphasis on observational and experimental study is promoted by collaborating with other educational resources such as regional science centres to foster students' intellectual curiosity and scientific point of view.
3. *Promotion of Cooperation of Universities, Scientific Societies, and Research Institutions with Schools*. MEXT is promoting science and technology education that allies schools with universities and research institutions. Researchers and engineers on the frontline of the latest developments give special classes and universities and research institutes provide training on cutting edge science for teachers.
4. *Rika-e Initiative (Development of advanced digital study materials for science and technology education)*. In addition to developing digitalised study materials for science and technology education using the latest research results from research institutions, MEXT is developing a system that will distribute them to every classroom in Japan.

The general objectives are defined by the government, but each individual initiative has its own set of objectives on which evaluation is based. Each institution is required to provide the funding institution with self-evaluation and a record of their actions.

Scientific Degrees Project (Italy)

www.progettolaureescientifiche.it/cgi-bin/WebObjects/pls.

An English summary can be found here:

www.progettolaureescientifiche.it/cgi-bin/WebObjects/pls.woa/wa/QWDirectAction/download?file=3.

The *Scientific Degrees Project* seeks to encourage young people to start enrolling for scientific degrees via measures that aim to stimulate their interest in this kind of subject, to provide more adequate preparation in basic science subjects at the upper middle school level, and increase the interaction between university and business in order to facilitate young people's entry to the workplace. Projects for teacher guidance and training are currently underway, and involve funding of € 2 m. In July 2006, notices of competition were published for 120 grants for enrolling for degree courses in chemistry, physics and mathematics. Other activities reserved more specifically for students are also underway, such as laboratories, workplacements and workshops, for which € 6.17 m has been set aside.

The project was promoted at national level by the Italian Ministry of Education (MIUR) and by the Science Dean's National Board (Con.scienze) in co-operation with the Association of Italian Industry (Confindustria), in the frame of the triennial plan (2004/06) for the University System.

A national working group defined the objectives and actions. A National Committee from the Ministry for Education, University and Research is in charge of selecting the projects and defining indicators for evaluation. Different teams are implementing and managing the various actions of the project. The National Committee will monitor the implementation process along the way and will evaluate the effect of each actions.

3.1.2. The top-down approach

In the top-down approach, the instigators design a set of specific actions, designate the actors in charge of implementing them and monitor the output. In the best situations, the top-down approach is built on the basis of a previous consultative and participative

Box 3.2. **Top-down action plans**

Promotion of young people in science and engineering (Korea)

An English summary can be found here: *http://english.moe.go.kr/main.jsp?idx=030101*.

Despite doing well in science subjects, Korean school students show relatively little interest in studying science. The government launched a trans-ministerial initiative to remedy this situation. The Ministry of Education drew up a 5-year plan in 2002 to enlarge research and experiments in primary and secondary science classes, with a total budget of KRW 270 billion to 2007. For students, science texts and curricula were designed to be more fun and easier. For teachers, research teaching manuals were provided, and voluntary meetings and research group activities among science teachers encouraged. Various off-campus events and science competitions involved students in collaboration with universities, the local community, and science and technology companies. The major tasks of the plan are:

1. At least one modernised lab in each primary and secondary school, and enlarge the supply of experiment tools, so that teachers will be able to conduct experiment with students.
2. Provide a sufficient volume of experiment manuals and supplementary study materials.
3. Improve teacher training programmes focusing on experiment-based classes, and encourage teachers to devise ways to improve science classes.
4. In addition to regular science classes in school, provide students with various science-experience opportunities such as "science camps" to help them become more interested in science studies and select science majors in future education.
5. Strengthen ties with the local community and reinforce the Education Ministry's governing role of science education, so that systematic administrative support may be possible.

Platform Bèta Techniek (Netherlands)

www.platformbetatechniek.nl.

In 2004 the Dutch Ministry of Economic Affairs, the Ministry of Social Affairs and Employment and the Ministry of Education, Culture and Science launched a Science and Technology Platform (Platform Bèta Techniek) to increase the number of new S&T graduates in 2010 by 15% compared to 2000 and to ensure that scientists and technologists are more effectively retained and used. The Platform's approach is to anchor S&T studies institutionally, from primary schooling to the labour market. The Platform is also developing a range of methods which schools can use to improve science curricula and teaching, participation by girls, development of partnerships, etc., as they wish.

Innovation and performance agreements are made with the school or a company regarding ultimate objectives. The core of this approach, then, is the school's autonomy. Nothing is imposed. Progress is monitored, and the results of monitoring are discussed with the school at auditing meetings so the school can see its strengths and weaknesses. In addition to its nationwide programme, the Platform is also active in the regions, collaborating with the business community, schools and regional and local government to establish and carry out science and technology agendas. The Platform's aim is to offer institutions – primary, secondary, vocational and universities – as much support and expertise as possible to ensure they have the capacity and tools to increase the quality and relevance of S&T studies and ultimately, the supply of S&T graduates.

process in which the different stakeholders have elaborated the fundamentals of the action plan. Korea and the Netherlands provide examples of this approach.

Acting on S&T interest and literacy for all

All students, indeed all citizens, should have some understanding of S&T, so a number of principles have to apply to all students, not just those who will later specialise in S&T, starting with the youngest. Children's interest in S&T is already visible at primary school, and even before this stage they are capable of "scientific" thought. Within a few years of starting school, many children have a positive or negative opinion about their own abilities to pursue certain courses of study. One longitudinal study concluded that the way students feel towards science and their own achievements in science classes at the US tenth grade level is "a strong predictor of subsequent science achievement in high school" (Simpson and Oliver, 1990). Longitudinal studies that followed groups of children between two ages (generally between 11 and 15) to show the variation in their interest towards science, suggest that once an attitude is formed, even at primary level, it tends to remain stable. Many of those who had made a decision in favour of or against a career in science and engineering had done so before age 14, with similar scores in both cases: 38% of the future physicists and 42% of those who were to do badly at science and go on to the arts side had made their decision away from science and engineering by the age of 14. Only 22% of future engineers, and 22% of the able non scientists had made up their mind by this age (Woolnough, 1994). Likewise, a longitudinal study of 13 to 16 year-olds found that ideas about the suitability of occupations in relation to gender are also formed early on, and are also stable over time (Furlong and Biggart, 1999). Retroactive studies that ask scientists about their career choices bear out these findings, with a significant majority (61%) saying they became interested in science before the age of eleven (Bayer, 2004).

Box 3.3. **Encouraging general S&T literacy**

Les Petits débrouillards – Smart Kids (International)

www.lespetitsdebrouillards.org/ (links to Belgian, Canadian, Czech, French, German and Slovak sites).

The association, now present in 14 or so countries, was founded in Quebec in the early 1980s. Generally this is an out of school activity, organised for example around a weekly club, with a range of learning materials the children can use at home. The idea is to teach scientific principles and the scientific method to children as young as four by encouraging them to carry out simple (safe) experiments using objects they can probably find in the house or cost very little to buy. For example, the principles of rocket propulsion are shown using a rocket made from paper, an empty film box, vinegar and bicarbonate of soda, while thermal gradients in water are illustrated using a bottle, a jar, some food colouring and a piece of string.

Educational experiment boxes (Flanders)

Nine activities are crammed into one large box aimed at making science and technology accessible to all pupils. The box includes experiments for instance with a polarization filter, sound in a vacuum, refraction and reflection, spherical lenses, propulsion, spring forces, Benham's disk, the bird in the cage, and the conservation of energy. This box can be used at both a "serious" scientific level and as entertainment.

Box 3.3. **Encouraging general S&T literacy** *(cont.)*

SciTech (Sweden)

Commissioned by the Swedish government, the National Agency for Higher Education created "SciTech", a five-year program to enhance public interest in science and technology especially among young adults. Another objective of the program is to stimulate the development of new methods of education in these fields. In order to offer a wide variety of courses and programs, for instance IT courses on the popular subject "computer knowledge", various types of institutions work together. Besides these courses, the program offers career counselling for careers in science and technology and individually tailored study plans. Courses, which prepare students for higher education are also organised. A unique characteristic of the initiative is its focus on gender equality. Special university classes for women have been arranged within the framework of the SciTech program. This may have contributed to the recent increase in the share of girls studying science and technology in Sweden. The funding of the Adult Education Initiative is being provided by the Swedish government, which attributes approximately 400 million euro annually to the project.

SINUS and SINUS TRANSFER (Germany)

http://sinus-transfer.uni-bayreuth.de/english_version.html.

The SINUS Programme was initiated after the outcome of the 1996/1997 TIMS-Study. The study showed that German students had obvious weaknesses and a common lack of understanding when confronted with math and science problems. Various schools all over the country were linked (in so-called Sets) and the teaching staffs improved their teaching methods, supported by the Maths Department of Bayreuth University. This was followed by SINUS TRANSFER, a super-regional Transfer-Programme in two sequences each of two years to include new school Sets in SINUS. At the beginning of the school year 2003/2004 the first sequence started at about 700 schools in 13 different federal states. The second sequence began in 2005 and included nearly 1 800 schools. In August 2007 most of the participating federal states started a third part of SINUS-Transfer. The SINUS Project aims to eventually cover the whole of Germany.

Joint Promotion of Mathematics, Science and Technology (MST) 2006-2009 (Norway)

www.regjeringen.no/en/dep/kd/Documents/Reports-and-actionplans/Actionplans/2006/Strategy-for-A-Joint-Promotion-of-Mathem.html?id=271539.

The overall aims of the programme are to improve the MST competence in the whole educational system, in working life and in the general public; increase the recruitment to working life and education in MST; and instil positive attitudes to MST among everyone in the educational system and among the general public. There are five more specific goals: strengthen MST in kindergartens and primary and secondary education; improve teachers' qualifications and teacher training; development of MST in higher education and research; provide the Norwegian labour market with the MST competencies it needs; increase the MST competence and improve the communication to the general public.

One danger with trying to make science interesting to children of whatever age is that it merely becomes entertaining, and that at best they remember an amusing trick, but forget, or never learn, the science it was supposed to illustrate. This may be the case with one-off visits to science museums or exhibitions, where the novelty and excitement of the day out are what make the biggest impression. The most successful efforts therefore will

seek to integrate the fun into an overall strategy based on generating and sustaining interest in the scientific process and practices. This can take place inside and outside the classroom.

3.2.1. Reforming curriculum content

Perhaps the most obvious place to start is with how S&T are taught. Three overarching criticisms of S&T curricula can be deduced from the previous sections and work elsewhere.

1. The first is that they are designed essentially for the tiny minority who pursue their studies to PhD level and do little to address the vast majority, who thus are more likely to see S&T as something irrelevant to their aspirations.
2. The second is that curricula, and indeed academic approaches to science in general, see science in terms of autonomous disciplines that perhaps correspond to how some academic research is still carried out, but do not reflect the multidisciplinary nature of much modern research, nor the interactions of S&T with other subject areas or with social concerns more generally.
3. The third is that curricula, and the schemes used to assess students, place far too much emphasis on theoretical aspects such as solving mathematical problems, and not enough on the practical aspects that characterise much of what many S&T professionals actually do.

The goal of science education is obviously to produce students who achieve a desired level of proficiency at different levels of education, either to allow them to pursue further studies or practice, or to understand the world in which they live and the some of the choices they as citizens have to make. The US National Academy of Sciences proposes a definition of proficiency based on the view of science as both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge (NAS, 2006). In this framework, scientific knowledge and the scientific process are inextricably linked, and a student who is proficient in science is one who can:

- Know, use, and interpret scientific explanations of the natural world.
- Generate and evaluate scientific evidence and explanations.
- Understand the nature and development of scientific knowledge.
- Participate productively in scientific practices and discourse.

The aim of the curriculum at early stages should be to stimulate curiosity, pleasure and interest, and to build self-confidence regarding S&T. However, science can be seen as something remote and threatening, with little, or negative, relevance to the lives of students. The social contribution of science and its significance for improving well-being should be emphasised. This can also be linked to the issue of role models, by teaching the history of important discoveries along with the lives of the women and men who made them. Technology as a tool is well-known and appreciated by most children, but they need to be informed about technology as a process of creation to elaborate new goods/devices and respond to social needs.

Listening to the teacher and copying what is on the blackboard, the so-called "chalk and talk" approach, is unlikely to achieve this. Priority should be given to deep understanding and methods over raw facts and knowledge. Practical experiments and hands-on help to stimulate interest. A balance has to be found with the more theoretical content. Cooperative learning has two significant positive outputs: developing soft/

Box 3.4. **Promoting S&T studies from primary education to the labour market: a cross-ministerial approach in the Netherlands**

In 2004, the Dutch Ministry of Economic Affairs, the Ministry of Social Affairs and Employment and the Ministry of Education, Culture and Science launched a Science and Technology Platform (Platform Bèta Techniek) to increase the number of new S&T graduates in 2010 by 15% compared to 2000 and to ensure that scientists and technologists are more effectively retained and used. The Platform's approach is to anchor S&T studies institutionally, from primary schooling to the labour market. The Platform is also developing a range of methods which schools can use to improve science curricula and teaching, participation by girls, development of partnerships, etc., as they wish. Innovation and performance agreements are made with the school or company regarding ultimate objectives. The core of this approach, then, is the school's autonomy. Nothing is imposed. Progress is monitored, and the results of monitoring are discussed with the school at auditing meetings so the school can see its strengths and weaknesses. In addition to its nationwide programme, the Platform is also active in the regions, collaborating with the business community, schools and regional and local government to establish and carry out science and technology agendas. The Platform's aim is to offer institutions – primary, secondary, vocational and universities – as much support and expertise as possible to ensure they have the capacity and tools to increase the quality and relevance of S&T studies and ultimately, the supply of S&T graduates.

professional skills, and being more attractive than other methods to female students. A number of in-school and out of school initiatives designed to introduce students to scientific problems and approaches are described below as well as some specially-developed teaching aids.

It may seem like stating the obvious to say that science education should be based on scientific principles and evidence, but curriculum design and teaching methods in many countries still refer implicitly or explicitly to cognitive research that may be decades behind the latest findings. Research shows that even pre-school children can develop sophisticated understandings of the phenomena around them and revise them in light of their experience in domains as diverse as linguistics, psychology, biology and physics, *e.g.* how objects move and how to interact with them, and how simple living things, plants, and animals work. Education needs to take better account of both the distinctive mind and individual conceptualisation of children at different ages, and schools could start to teach children from their natural conceptions (and misconceptions) about reality in order to achieve a real understanding of the scientific concepts that describe it (Gopnik, 2000).

Parents and educators can do much to motivate and channel children's interest in science starting from the early years of schooling (including correcting their misconceptions about scientific concepts.) This requires a consistent, long-term effort and the curriculum has to develop a range of skills, often in association with other parts of schooling, but sometimes with precise requirements for S&T. For example, writing up a science project or experiment is not the same as writing a history essay or a story. Learning the scientific method also demands learning to do research, *i.e.* how to observe a phenomenon, formulate hypotheses to explain it, design an experiment to test these hypotheses and evaluate the results.

Box 3.5. **Curriculum content reform**

A Curriculum for Excellence (Scotland)

www.scotland.gov.uk/Publications/2006/03/22090015/11.

The review of the science curriculum started by identifying the knowledge, understanding, skills and attributes that would be required by every young person by age 15 to prepare them for their future lives and careers. The "big ideas" of contemporary science were identified and grouped under three main lines of development: Our living world; Our material world; and Our physical world.

The proposed outcomes are fairly broad: suggesting appropriate learning experiences rather than prescribing specific objectives or teaching and learning sequences. Outcomes for knowledge and understanding, skills and attributes are fully integrated. In total, they represent the essential learning that most 15 year-old would be expected to experience and demonstrate.

Teachers would be able to draw from these to develop relevant teaching contexts and activities, both within and beyond science, to a depth appropriate for the stage or class.

Unhelpful repetition which currently appears across the sciences will be removed. Similarly, future analysis will help to remove duplications and ensure consistency of expectations across curriculum areas.

The proposals will support an extension of experiential learning from the early years into early primary school and beyond. In the remaining years of primary school, teachers will have the opportunities to create teaching contexts that take advantage of local events and circumstances and the needs and interests of the young people they teach.

In secondary schools, the proposals will promote classroom talk, group discussion and debate about the benefits and risks associated with the applications of scientific knowledge. Learners will have the opportunity to become actively involved in their learning and to deepen their understanding of the big ideas of science. Through involvement in a wide range of open-ended experiences, challenges and investigations they will develop critical thinking skills and appreciate the key role of the scientific process in generating new knowledge.

***LUMA* (Finland)**

www.oph.fi/SubPage.asp?path=1;443;6717;7806.

LUMA, an acronym of the Finnish words meaning natural sciences and mathematics, was launched by Finland's National Board of Education to develop the teaching of mathematics and the natural sciences. The Ministry of Education extended the Programme to embrace players outside the school system as well, and in 1996 announced an extensive programme to develop knowledge in mathematics and the natural sciences (the LUMA Joint National Action) for 1996-2000.

To support the Joint National Action, the Ministry of Education appointed a working group (The LUMA Support Group), whose task were for instance to encourage participation by various responsible organisations in the implementation of the Programme and to monitor and support the implementations of the objectives and to organize assessments (interim and final) of the Programme.

Higher education institutions have provided schools with their equipment and expertise, given teachers supplementary training and carried out research and researcher training projects relating to the learning and teaching of mathematics and the natural sciences

The Ministry of Education and National Board of Education allocated a total of EUR 34 million in development funds for the Joint National Action and the National Board of Education´s project group has devoted 20 man-years during the project to developing teaching in mathematics and the natural sciences.

This is asking a lot of teachers, many of whom at primary level especially, may have little or no scientific training. The outcomes will be more satisfying for student and teacher alike if the aim is to teach the scientific method and a few central concepts that can be applied and developed at different stages rather than trying to cover too much. A child who has grasped that science is about questions as well as answers, team work as well as individual effort, and failures as well as triumphs is less likely to be discouraged by the difficulties of the subject and any personal lack of skills or knowledge than one who is taught science as an ever more complicated set of formulas.

In the same way, teachers who understand the scientific method need not feel that they should know the answer to everything that might come up in class. They can admit that they don't know this particular thing, but they do know how to find out about it. Moreover, this can be a useful introduction to the scientific method, which should be considered in science curricula in the same way it is in scientific endeavours generally, *i.e.* an integral part of the process, open to discussion as to the best approach to adopt to a particular problem. Students should also understand that the scientific method is not limited to experiments, that scientists also use observation, analysis, etc.

At secondary level, students have some choice as to the subjects they study, which makes curriculum design and teaching more difficult, since some students see science as their main subject, others may be interested in science but prefer to choose another path, yet another group can't wait to drop it, and so on. None of these types of students will be motivated by a curriculum that sees science as a set of independent subjects (physics, chemistry, biology, etc.) practically separate from each other, and utterly divorced from the concerns of society and students, whose principle demands are to memorise lists of formulae and other disconnected pieces of information.

In this context, even what should be major attractions of science – its new discoveries and disciplines and its constant additions to the store of human knowledge, can become handicaps if they are reduced to yet another thinly spread layer of facts and figures to assimilate into an already overcrowded programme. This reinforces the point made earlier about concentrating on a core of knowledge that can deepen at each successive stage rather than trying to teach a little of everything. An emphasis on the fundamentals does not mean being able to recite the great discoveries of the past, rather it means equipping the students with the means to understand how modern science works and how it contributes to many of the things students find interesting. For example, students learning about magnetism are more likely to have seen a computer hard drive than the oft-quoted crane used to lift junk, and the hard drive can also be used to introduce nanotechnologies.

University curricula and teaching may thus be designed for the minority of students whose aim is a career as a researcher in academia or industry. If this is so, universities are failing in their duty not only to the other students, but to society as well. As stressed throughout this report, society needs a strong base of scientifically literate workers and citizens, and what is taught at tertiary level must reflect the skills that are needed in the economy as a whole. These include so-called the "soft skills" vital to efficient insertion into the world outside the university, including communication, project management, and teamwork (important for carrying out scientific work too.) For example, very early in their career, graduates may have to take on management responsibilities, but the university approach to subjects like maths, physics and chemistry is unlikely to prepare them for this.

Apart from the direct practical benefits to science students, an approach that seeks to present science as part of the basic culture of an educated person and prepares scientists for their role in society and in working with others could have a positive influence on recruitment to science courses. Including a significant amount of general education, including languages, politics and economy, in S&T tertiary education would contribute to fighting the image of S&T as narrow subjects and scientists as out of touch with society.

3.2.2. Reforming curriculum structure

In most countries, students have to make a critical choice about their future orientation around the age of 15 (at the junction between lower and higher secondary education). Most of the time, this choice is based upon limited information, and hence follows guidance from teachers and parents, and is linked to previous results in school. In many cases, this choice is not correlated to the student's intrinsic capacities or actual taste. While "good" students usually follow "elite" tracks that lead to a broad variety of higher education possibilities, and often do follow courses with some mathematics and/or S&T content, this is not necessarily the case for those who may have encountered difficulties

Box 3.6. **Curriculum structure reform**

Tertiary level education with economic support for adults (NT-SVUX) (Sweden)

In an effort to increase the number of graduates in science and technology as well as reduce unemployment in some categories of workers, financial support (grants and loans with favorable conditions) was given to targeted groups (adults without S&T background, 28-48 year-olds having been fully employed for at least 5 years). A total of 10 000 students benefited from this support between 1995 and 1999. A 60% success rate was observed, with 90% of those students who actually followed the three-year courses having a full-time job in 2001.

The technical-scientific basic year (Sweden)

This programme, which was planned to last only one year (1992/93) was finally continued. The objective was to give "a second chance to choose science studies" to students having elected other fields at high school. For this, a special year was set up to allow students who did not follow science courses in high school to build the knowledge they needed to be admitted in tertiary level science courses. Success in this basic year gives the student a guaranteed place at university (in a selective system). The success rate in this programme is fairly high, and those who follow the basic year show performances equivalent to their fellow students in university courses later on.

The Transition Year (Ireland)

www.ncte.ie/transition/index.html.

Students in Irish second-level schools, after they have completed the Junior Certificate Examination – usually around 15 years of age – may opt to follow a Transition Year Programme. A Transition Year offers pupils a broad educational experience with a view to the attainment of increased maturity, before proceeding to further study and/or vocational preparation. It provides a bridge to help pupils make the transition from a highly-structured environment to one where they will take greater responsibility for their own learning and decision-making. Pupils participate in learning strategies which are active and experiential and which help them to develop a range of transferable critical thinking and creative problem-solving skills.

for various reasons (health or family problems, lack of maturity, etc.). Similar problem also occur at the end of secondary education, when students have to choose their higher education fields of study.

Although young people are usually fairly flexible, and well able to correct their study path should they wish, the curriculum structure rarely allow them to do so. Thus, in most cases, students who chose a non-S&T track at the age of 15 are unable to come back to such a field of study later on, even if they wish to do so.

Making the path of S&T studies more permeable and allowing students a second chance to access S&T studies at later stages in the education system is therefore an important asset to "get back" potential students in S&T. Indeed, such a strategy is being set up in a few OECD countries, for instance Sweden, Ireland and the United Kingdom, and has proved fairly effective. In the Swedish "Basic year" programme for example, 60% to 70% of the students who registered in a special year designed for students who had not followed science courses in high school were admitted successfully the year after in S&T at university. Furthermore, no difference in success rate was observed between "basic year" students and students coming directly from secondary upper level.

3.2.3. Effective pedagogy

Little will be gained from curriculum reform if teaching methods are inappropriate. Teaching of S&T has its own set of knowledge and skill requirements and in 2002 the New Zealand Ministry of Education published the results of an international survey of science teaching that summarised the main characteristics of effective science education as follows.

- The existing ideas and beliefs that learners bring to a lesson are elicited, addressed, and linked to their classroom experiences.
- Science is taught and learned in contexts in which students can make links between their existing knowledge, the classroom experiences, and the science to be learned.
- The learning is set at an appropriate level of challenge and the development of ideas is clear – the teacher knows the science.
- The purpose(s) for which the learning is being carried out are clear to the students, especially in practical work situations.
- The students are engaged in thinking about the science they are learning during the learning tasks.
- Students' content knowledge, procedural knowledge, and knowledge about the nature and characteristics of scientific practice are developed together, not separately.
- The students are engaged in thinking about their own and others' thinking, thereby developing a metacognitive awareness of the basis for their own present thinking, and of the development of their thinking as they learn.
- The teacher models theory/evidence interactions that link conceptual, procedural, and "nature of science" outcomes and discussion and argumentation are used to critically examine the relationship between these different types of outcomes.
- Key features of the nature of science are made visible to students and they develop a metacognitive awareness of the similarities and differences between their own personal theorising, and scientific theorising.

- Conversations and investigative skills are scaffolded by the teacher, with explicit modelling of the type of discourse/activity that is appropriate and of the type of outcome/product to be achieved.
- The role of models, modelling, metaphor, and analogies in science is made an explicit focus of practical investigation and of discussion.
- Teachers engage in formative interactions to help students as they learn.

There is also a danger that a report by the European Commission called a "subculture" in science teaching, at upper secondary level in particular (EC, 2004). At this level, teachers have a science qualification and (hopefully) a keen interest in the subject, but they see teaching only in terms of their own speciality. This may be suitable for the very few students likely to go on to study the same subject, and a slightly bigger group who will study some other science subject, but the impact on other students' is likely to be catastrophic.

Addressing all these demands requires an integrated approach, not only in the sense of integrating the various aspects and contents of science teaching into a coherent whole, but integrating science into the general culture of students. This includes dealing with what some practitioners might call the "non-scientific" side of science, *i.e.* science as a social construct. Providing the context in which discoveries were made and the controversies and uncertainties related to modern discoveries helps to break down the prejudice that science is something abstract, only of interest to people who are or would like to be scientists themselves. Educators can capitalise on students' interest in topics such as the environment or world hunger to stimulate an interest in science, in these cases for example, the science of global warming or the role of genetically modified crops could be discussed.

Teacher training has to incorporate these factors, and science should be a compulsory part of training for primary teachers. In addition to introducing the actual S&T content they will have to teach, training courses should also equip trainees with an understanding of how children conceptualise science and how this evolves at different ages. Secondary teachers also need training not only in how to teach science, but also in disciplines other than that which they studied at university. There often seems to be an assumption that Teachers at every level should also have opportunities for in-service training.

At tertiary level, one might expect some of the challenges outlined above to disappear, or at least be marginal. The students have chosen science, and presumably have an aptitude for it. Yet dropout rates in the first years of science programmes are higher than in other disciplines. Some of this may be due to poor orientation of students, but the fact that science is affected so consistently suggests that they way it is taught needs to be revised. One of the most obvious steps, already mentioned, would be to provide university teachers with training in how to teach. At present, a knowledge of the subject matter is deemed sufficient by many institutions, and the high value attached to research in university rankings and career moves reinforces the notion that teaching is something inferior. For example, one of the most popular of the many lists of "top" universities, the Shanghai Jiao Tong University ranking, is drawn up on the basis of "Nobel Laureates, Fields Medals, Highly-Cited Researchers and a significant amount of articles indexed by Science Citation Index-Expanded". It does not mention teaching or dropout rates.

Box 3.7. **Moving away from "chalk and talk"**

***La main à la pâte* "Hands-on" (France)**

www.inrp.fr/lamap/.

This programme was launched in the late 1990s by the Ministry of Education on the initiative of Nobel Prize laureate George Charpak and the Academy of Sciences. Volunteer teachers were trained and given support to teach science in a more practical and interactive way. Actions in the 40 million franc programme included:

- Increasing the share of science in in-service training of teachers.
- Providing funds to purchase pedagogical and scientific equipment.
- Developing and supplying tools to help teachers implement the program and the new curricula, methodological and pedagogical guides, internet services.

The programme also involved the creation of committees at national level and also at the different levels of local government and education administration to organise co-operation among the actors of the program – directors of education, inspectors, institutes for teacher training, scientific institutes, etc.

The programme involved around 2% of students in French schools and in 1999 an evaluation concluded that the knowledge acquired is well-organised and assimilated, and children experience the importance of rationality in understanding the world. Interestingly, a number of positive outcomes not specifically related to science were also noted. Students learned to express themselves better and developed the ability to work in groups and elaborate a consensus. However, the evaluation also stressed that training teachers in the new methods was resource intensive. In 2001-2002, a new curriculum was issued, coherent with the programme for renewed teaching. The emphasis is on methods based on the pupils' questioning and experimental investigation and group work is encouraged. The programme is now also available for lower-secondary education. "La main à la pâte" model has been exported to a number of other countries, and forms the basis for the European Union-supported programme Pollen (*www.pollen-europa.net/?page=CLDGDJVwskY%3D*).

Let's talk science (Canada)

www.letstalkscience.ca/main/.

Let's Talk Science in-class workshops provide innovative learning opportunities involving fun and discovery as a basis to facilitate a student's learning and skill development. All in-class workshops are curriculum matched and use guided discovery through hands-on activities. Many have a take-home component so students can share their achievement with their parents.

***Chip, chip, chip, hurray* (Belgium)**

Interactive experimental box for ICT and introducing chips for use in the classroom. The box is comparable with the educational experiment boxes described above, but with one large difference : the boxes are provided with support for the teacher, meaning that there is permanent helpdesk available. Indeed, a demonstration session is given and a service desk is available for teachers when they try the box on their own. Analysis of the policy and action plan and some of the activities revealed that the educational experiment boxes were sometimes left aside, simply because such a helpdesk was lacking. The project is designed as part of to provide a sound base for a whole educational trajectory (from 2.5 year-old to 18 year-old).

3.2.4. Promoting diversity

Female students and students from under-represented minorities present a considerable potential for increasing S&T enrolments, but the factors that affect their choices and success in these disciplines are difficult to act upon, and sometimes it is extremely hard even to distinguish the factors linked to gender, and ethnicity in particular from other socioeconomic factors, as a number of complex interactions are involved.

Many surveys have shown clear differences between boys and girls in their experience with, interest in, and attitudes to science and engineering, so it is not surprising to see these attitudes transposed into differences in their choice of studies. Furthermore, girls tend to show a stronger interest in people rather than facts or "things", and these differences are amplified in the way S&T are taught, and in the perception of S&T careers. These differences do not appear to be related to ability, since girls tend to succeed well in S&T, especially in the early stages. Young female students do however suffer from stereotypes in relation to external expectations (those of parents, teachers, and society in general). Despite having marks at least as good as boys, girls are usually not encouraged to pursue S&T career paths by their families, teachers, and career advisors. Some research suggests that this gender bias starts practically from birth. A study of family behaviour in science museums found that both parents, but especially fathers, explained the content of interactive science exhibits three times more to sons than to daughters, even to children as young as one, while parents were twice as likely to explain the content of interactive music exhibits to daughters than to sons (Crowley, 2000).

The teaching process tends to reflect stereotypes too: for example, boys are praised for creativity and imagination, but girls for more mundane achievements such as hard work or perseverance. Girls tend to undervalue their own performance, and hence their ability to pursue S&T. They also lack role models (famous scientists, family members, etc.). Several studies have shown that having family models may strengthen confidence in girls' ability to undertake S&T studies. In certain respects, these stereotypes are also true for students belonging to some minorities. Both girls and minority students may find themselves isolated in the homogeneous, male-dominated majority group formed by students studying S&T. Some experts are working on the re-engineering of the education process to offer equal opportunity to both genders, but no consensus has yet emerged concerning the assumptions, methods, or results that can be achieved.

In tertiary education, the number of female students has increased more rapidly than that of males, but the proportion of women choosing S&T studies is still lower than that of men. In most countries, women constitute less than 25% of computing and engineering students, but are systematically more numerous than men in life sciences. Even if the share has often increased more clearly in countries that had the lowest proportion of female S&T students, trend analysis suggests that the proportion of female S&T graduates may hit a 40% "glass ceiling" even in the most "effective" countries. This implies that women are facing obstacles that have nothing to do with their ability. The table below summarises many of the most common myths women have to fight against. It is based on experience in the United States and analyses of why women there are not fulfilling their potential in academic science and engineering, but many of the findings are relevant across OECD countries, where women's representation diminishes steadily at each successive stage from primary school through to head of faculty, a phenomenon labelled the "leaky pipeline".

Box 3.8. **Promoting diversity**

National Science Foundation Research on Gender in Science and Engineering Program (USA)

www.nsf.gov/pubs/2007/nsf07501/nsf07501.htm.

The program seeks to broaden the participation of girls and women in all fields of science, technology, engineering, and mathematics education by supporting research, dissemination of research, and extension services in education that will lead to a larger and more diverse science and engineering workforce. Typical projects contribute to the knowledge base addressing gender-related differences in learning and in the educational experiences that affect student interest, performance, and choice of careers; and how pedagogical approaches and teaching styles, curriculum, student services, and institutional culture contribute to causing or closing gender gaps that persist in certain fields. Projects are expected to disseminate and apply findings, evaluation results, and proven good practices and products.

Women give new impetus to technology (Germany)

www.frauen-technik-impulse.de.

The main objective of this non-profit organisation ("Competence Center Technology-Diversity-Equal Chances") is to help shape Germany's path towards becoming an information – and knowledge-based society. To this end, it develops and carries out a wide range of initiatives and projects that exploit the potential of women and men in all spheres of society and work. The organisation groups its activities into three areas of expertise: digital integration, focusing on equal access to changed lifestyles and labour markets; training, further education and careers, concentrating on gender-oriented vocational and life planning and the transition from school to work; higher education, science and research, intensifies efforts to promote talented young women in relevant academic subjects and research. The goals of the measures and projects of the organisation are to strengthen media literacy and increase Internet use; to foster new ways of thinking about career orientation and life planning; and to promote equal opportunity and excellence in higher education, science and research.

The Great sEXPERIMENT (Belgium)

www.ecsite.net/scripts/uploaded/the_great_sexperiment_light.pdf.

"The great sExperiment" is an interactive exhibition about the talents of women and men. By means of more than 40 interactive exhibit visitors take part in an experiment to find out what women can do better than men or what men can do better than women. People of all ages can discover their own and each other's talents and skills. The exhibition lets women and men discover that science and technology are not exclusively "men's" business.

The ETHNIC Project (EU)

http://ec.europa.eu/research/science-society/index.cfm?fuseaction=public.topic&id=544.

The European Commission's ETHNIC (Raising Awareness of Science and Technology Among Ethnic Minorities) project ran from 2003 to 2005. The main objective was to raise awareness of S&T among ethnic minorities, emphasising engineering, IT and biotechnology. The target beneficiaries of the 80 million euro project were young people from ethnic minorities, parents, the S&T community, and the media. The project was based on a multi-level programme of activities, encompassing after-school sessions, info-days, seminars, consultative panels and exhibitions. Project partners came from Austria, the UK, Slovenia, the Czech Republic, Hungary and Italy. The Slovenian and British partners are carrying on with the development of tools, primarily training guides.

Table 3.1. **Myths and reality concerning women in science and engineering**

Belief	Evidence
Women are not as good at mathematics as men.	Female performance in high school mathematics now matches that of males.
Abolishing underrepresentation on faculties is only a matter of time; it is a function of how many women are qualified to enter these positions.	Women's representation decreases with each step up the tenure track and academic leadership hierarchy, even in fields that have had a large proportion of women doctorates for 30 years.
Women are not as competitive as men. Women don't want jobs in academe.	Similar proportions of men and women science and engineering doctorates plan to enter postdoctoral study or academic employment.
Women and minorities are recipients of favouritism through affirmative-action programs.	Affirmative action is meant to broaden searches to include more women and minority-group members, but not to select candidates on the basis of race or sex, which is illegal.
Academe is a meritocracy.	Although scientists like to believe that they "choose the best" based on objective criteria, decisions are influenced by factors – including biases about race, sex, geographic location of a university, and age – that have nothing to do with the quality of the person or work being evaluated.
Changing the rules means that standards of excellence will be negatively affected.	Throughout a scientific career, advancement depends upon judgments of one's performance by more senior scientists and engineers. This process does not optimally select and advance the best scientists and engineers, because of implicit bias and disproportionate weighting of qualities that are stereotypically male. Reducing these sources of bias will foster excellence in science and engineering fields.
Women faculty are less productive than men.	The publication productivity of women science and engineering faculty has increased over the last 30 years and is now comparable to men's. The critical factor affecting publication productivity is access to institutional resources; marriage, children, and eldercare responsibilities have minimal effects.
Women are more interested in family than in careers.	Many women scientists and engineers persist in their pursuit of academic careers despite severe conflicts between their roles as parents and as scientists and engineers. These efforts, however, are often not recognised as representing the high level of dedication to their careers they represent.
Women take more time off due to childbearing, so they are a bad investment.	On average, women take more time off during their early careers to meet their caregiving responsibilities, which fall disproportionately to women. But, over a lifelong career, a man is likely to take significantly more sick leave than a woman.
The system as currently configured has worked well in producing great science; why change it?	Career impediments based on gender or racial or ethnic bias deprive the nation of talented and accomplished researchers.

Source: Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering, NAP, 2006 (*www.nap.edu/catalog/11741.html*).

A number of steps can be taken to address gender inequalities and to encourage girls and young women in science. Apart from being aware of gender differences in science teaching, improving the image of science, engineering and technology, and adapting careers materials and services to attract girls and young women into scientific professions. These might also be relevant for some ethnic groups, but countries who do not collect data on ethnic backgrounds cannot be expected to know objectively if they are facing a problem in minority participation. Collection of gender-sensitive data and the construction of good indicators are first steps to understanding the nature and extent of the challenge. When programmes are being designed, clear objectives should be stated from the outset, and evaluation criteria and milestones by which to judge whether they are succeeding should be defined. General mission statements about opportunity for all and fulfilling potential are useful for summarising goals, but they are too vague for judging whether a programme is achieving its objectives or whether it should be modified or abandoned.

Influences such as peer groups and family are difficult to influence through policy, but other aspects can be targeted:

- Adapt the learning context and approach to make it more attractive.
- Provide female students and those from minority backgrounds with opportunities to identify with S&T professionals.

- Provide female students and those from minority background with opportunities to develop self-confidence as regards to S&T studies
- Improve the perception that S&T careers are difficult to balance with personal/family life. Subjects such as impact of the family on scientific careers need to be investigated more extensively, as does the effect of policies designed to retain and promote women and men in science.

Ideally, a uniform S&T educational system should be applied for all students, and should allow all students to achieve their full potential, without subtle or overt discrimination. To help achieve this, female students should benefit from priority measures, sometimes called "gender mainstreaming". However, this should preferably not be achieved via programmes that are targeted at "girls only" as such labelling often lowers their credibility for various stakeholders. At the same time, there is some evidence that single-sex classes can help girls to develop confidence and learn better in some areas.

The learning context and approach should be modified to make them more attractive to female students. For example, the benefits of S&T for society should be stressed, since altruism and the desire to help others are often important for female students in their choice of career, including those who choose S&T. This helps to explain why life sciences are popular among female students.

Mentoring projects should be encouraged to support women and minority students undertaking careers in S&T.

Encouraging a change in work culture, with emphasis on policies and support systems that favour the integration of work and life outside work for women and men. This could include, for example, new models for childcare, flexible working hours and places, support for re-entries (after maternity leave), and support for family mobility (not only for one member of the family), among others.

Mechanisms for involving women scientists more actively in the policy process, and in designing and managing research programmes and resources. Support could be provided through networking and mentoring systems.

Addressing future S&T-based professionals

In addition to the actions outlined above, a number of more specific actions designed to encourage future S&T students at higher levels of education and in employment can also be identified. Children entering secondary education are usually interested in science and technology and very positive about learning more or even choosing it as a career. But this interest declines as they grow older, and by age 15 has often declined quite sharply (Osborne, 2003). Fifteen is also the age when gender differentiation starts to translate into choices, and when key future orientations are set in most educational systems. Actions proposed for the general student body are still relevant at this age, but they should be supplemented by specific actions that show in more detail the attractions of S&T, *e.g.* meeting S&T professionals, exposure to cutting-edge science and technology and their use in modern life, debates on controversial issues concerning the role and social relevance of S&T, and actions directed towards a "humanisation" of science teaching. Teaching should also concentrate more on scientific concepts and methods rather than on retaining information only.

In many systems, once students have chosen their main orientation it is difficult to change, which means that students who, for whatever reason, do not choose S&T as their main subjects are often definitively excluded from these fields. Giving a second chance to

Box 3.9. **Addressing future professionals**

***Jet-Net* (Netherlands)**

www.jet-net.nl/start.html.

Jet-Net was set up in 2002 between five major companies, the economics and educations ministries, Dutch employer's organisations and intermediary organisations in the education sector. Its prime aim is to stimulate increased interest among high school students to pursue their studies and future career in S&T. Its target is to increase of annual enrolment in higher science and technology education by 5 000 students. It now includes 28 active industrial companies, with 180 individual engineers and technologists who participate in school briefing sessions for students; 130 participating schools (= 25% of all pre-tertiary schools in the Netherlands) with 25 000 students taking part in activities each year; 300 science and maths teachers; and an average input from partners of 25 to 35 euro per school/year. Special teams are assigned to assist the Jet-Net companies in quality development and in formatting the various types of program components, thus facilitating effective relations with the schools. Programs are established between individual schools and companies, ideally covering the entire school period. They are geared to add practical context to the science curriculum but also to enlighten students on the broader career prospects in industry and technology.

Promoscience (Canada)

www.nserc.ca/promoscience/index_e.htm.

PromoScience is a programme operated by Canada's Granting Agency for university and college research in the natural sciences and engineering (NSERC). It provides support for organisations opening science and engineering doors for Canada's young people. PromoScience grants may be used to cover expenses relating to program delivery and to many of the operational costs of the organisation. PromoScience grants support organisations that: work with young Canadians to inspire an interest in science and engineering; motivate talented young people to study science and engineering; encourage young people to consider careers in science and engineering; bring science experiences to groups who are traditionally under-represented in scientific and engineering careers; train the teachers who teach science, math and technology.

Science team K (Denmark)

www.scienceteam.dk/.

One secondary school and 17 surrounding primary schools in a minor provincial town, Kalundborg (the K of the project name), were selected. The goal is to increase recruitment from primary school to science in secondary school, and from secondary school to university studies in the fields of science, medicine and engineering. The focus is on the teaching of physics and chemistry. A spectrum of remedies are implemented, partly inspired by the CienciaViva experience, including funding of teachers' innovative ideas. Sixty-five science teachers are actively engaged and local industrial companies are also involved.

Ciencia viva (Portugal)

www.cienciaviva.net/.

Ciencia viva proposes short placements for students in research laboratories and includes a programme fostering the twinning of schools and scientific institutions. "Science in the Holidays for Young People" provides work experiences for students in research laboratories during one or two weeks in the summer. 4 000 secondary school students have participated since 1997. Field activities are organised in collaboration with research institutes, universities, associations and local authorities. Astronomical observations, field trips with biologists and geologists, visits to lighthouses guided by naval officers and visits to engineering facilities like bridges and dams, power stations, antennas are available for a non specialized public. National Scientific Awareness Campaigns stimulate and provide the opportunity for personal contact with science specialists and institutions in the different fields.

high school students who have elected other fields, through a special year to acquire the knowledge necessary to pursue tertiary S&T courses has proved to be very successful, with excellent success rates, provided the right incentives are set up.

Courses that are highly specialised early on can deter some students who may be interested in S&T, but may not have the skills or confidence to enrol. Adaptation of the offer of S&T courses to new targets (women, students from average academic level, students from less-privileged groups, students from minority groups) can be achieved in a number of ways without "dumbing down" the curriculum, *e.g.* including a significant quantity of relevant material from other disciplines such as business studies; putting a stronger emphasis on soft skills (communication, team working, planning, project management, etc.); promoting teaching methods that include more interactions; and designing education paths that provide opportunities to enter the job market at various stages.

Coping with students' diverse interest and experience is one of the biggest challenges facing the teacher in the classroom in any discipline, and teachers are usually aware of how a student's background can influence attitudes and performance. This is already hard enough, but the nature of S&T studies adds further layers of complication, and no single teaching strategy will produce the desired results given the variety of profiles likely to be present in any one class. Some pupils will be motivated by the more abstract, intellectual challenges, while others will be stimulated by the practical applications and find theory boring or difficult. Likewise, some students will react better to a highly-structured approach to teaching where each step is clearly indicated from the outset, while others will resent the constraints and do better with less predictable methods such as projects where the result is not guaranteed. Again, some students work best by cooperating in groups, while others are stimulated by individual effort and competition.

Unless their family background brings them into contact with S&T professionals, many students may have little notion of the diversity of possible careers, working conditions, etc. and decide against S&T on the basis of inaccurate stereotypes. Provision of accurate information is an important aspect of any policy to increase the attractiveness of S&T studies and careers. This encompasses not only the information provided to students, but also interactions among all the stakeholders (education, scientists, business, etc.).

The first year of science programmes often has the highest drop-out rate. Some of this may be due to poor teaching and badly-designed courses. At tertiary level, the opposite problem to that found at primary may be common: teaching staff have more than enough technical knowledge of their subject, but little or no training in how to teach. Moreover, if career advancement depends mainly on research performance, there may be less motivation to invest in improving teaching skills.

Conclusions

As the programmes described above suggest, encouraging interest in S&T studies across the whole spectrum of students' abilities, motivations and career plans has to take to take account not only of the educational system in its entirety, but also of a host of factors outside school (and outside the control of the education system). Ultimately, it is a question of convincing students to choose S&T studies and engage with what goes on the classroom. They are more likely to do this if science and technology education are seen as relevant to all citizens, not just experts. What is taught and how it is taught have to be seen to address contemporary developments and concerns, and students should leave science

classes having acquired insights and skills that will stay with them long after they have forgotten lists of facts and figures.

This requires a multilevel approach to discovering S&T and building on the intrinsic interest of these subjects, which implies constant awareness of how actions targeting one aspect are influenced by, and influence in their turn, other parts of the system. This does not mean central planning of the entire process to avoid unwanted outcomes and interactions. It does mean creating mechanisms that allow system-wide monitoring to modify or even abandon schemes that are not producing the desired results, and constant efforts to highlight and reinforce positive initiatives. "Initiative" is a key concept here. Successful schemes create positive feedback among the various actors, encouraging them to propose ideas and to adopt and adapt interesting proposals from elsewhere. This implies involving all stakeholders – the students themselves, their families, schools, employers, S&T professionals and policy makers. It also means being aware of and open to actions from other groups, including those from other countries. One of the most heartening conclusions to be drawn from this survey is that although much concern is expressed about the evolution of interest in S&T studies, there are also impressive pools of imagination, commitment and energy that can be drawn upon to address this concern.

However, an important component of any policy designed to address the problem of young people's interest for S&T is the presence of evaluation criteria and indicators of success. With a few exceptions, most initiatives have been launched and carried out without any rigorous evaluation procedure or set targets, which makes any evaluation of their success difficult. In most cases, the only indicators available are the number of students who participated in the scheme and a few subjective assessments from questionnaires. Built-in indicators and defined objectives are thus often lacking, which also prevents the sharing of best practices between interested countries.

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Chapter 4

Overall Conclusions and Recommendations

In recent years, S&T student numbers have been increasing in absolute terms, but decreasing in relative terms

Over the past 15 years, most OECD economies have experienced a large increase in the number of students in higher education, reaching over 30% in 10 of the 19 countries studied. The absolute number of students in S&T fields shows an overall increase too, but the proportion of S&T students has steadily decreased during the same period. Some disciplines do better than others. Engineering students account for 40% to 60% of S&T students in most countries, especially at the new tertiary entrant and graduate levels, and are characterised by a stable or positive enrolment trend over the past 10 years. The situation for physical sciences and mathematics is the opposite, where a decline is often seen in the absolute number of students, and the proportion of students in such fields was actually halved between 1995 and 2003. On the other hand, the proportion of students in the life sciences has remained mostly stable, due primarily to an increasing number of female students. The number of computer science students has increased dramatically, perhaps as a consequence of shifts in student choice within the overall domain of S&T.

Recommendation

- Given that enrolments are declining in certain fields, governments of OECD countries need a better understanding of the impact of this phenomenon on their economies and on society in general. Specifically, the Global Science Forum activity described here should be followed by a complementary effort to understand future demand for S&T graduates at all levels. The comparison of the likely supply and demand would determine the urgency of undertaking new efforts to change enrolment numbers.

Women are still strongly under-represented in S&T studies

Although the number of female students in tertiary education has increased more rapidly than that of males, the proportion of women choosing S&T studies still remains below 40% in most OECD countries and women constitute less than 25% of computing and engineering students. Women are however systematically more numerous than men in the life sciences The highly gender-dependant choice of discipline may be linked to the negative pressures and external expectations affecting female students. Persistent stereotypes weigh heavily on female student choices throughout their education (a phenomenon that can also affect minority students).

Recommendations

- Female students should benefit from priority measures, as they constitute a large reserve of possible S&T students. However, this should preferably not be achieved via programmes that are targeted at “girls only” as such labelling often lowers their credibility for various stakeholders.

- Ideally, a uniform S&T educational system should be applied for all students, and should allow all students to achieve their full potential, without subtle or overt discrimination.
- Reforms are needed in teacher training, curriculum and role model development. The learning context and approach should be modified to make them more attractive to female students. For example, the benefits of S&T for society should be stressed.
- Multidisciplinarity and student interactions should be promoted.
- Mentoring projects should be encouraged to support women and minority students undertaking careers in S&T.

Student choices are mostly determined by their image of S&T professions, the content of S&T curricula and the quality of teaching

Student decisions about study and career paths are primarily based upon interest in a particular field, and on their perception of job prospects in that field. Educational content and curricula play an important role in raising and maintaining young people's interest in S&T. Positive contacts with science and technology at an early age can have a long-lasting impact. Negative experiences at school, due to uninteresting content or poor teaching, are often very detrimental to future choices.

Furthermore, curriculum structures can also play an important role in preventing pupils from pursuing their natural preferences. Accurate knowledge about S&T professions and career prospects are key elements of orientation, but are currently fraught with stereotypes and incomplete information. Science and technology face increasing competition for good students from new, more fashionable subjects in higher education.

Recommendations

- Students must have access to information about S&T careers that is accurate, credible, and avoids unrealistic or exaggerated portrayals. It should be compiled by independent observers, and made available to the education community, parents and students. Better information on S&T jobs should also be provided through direct contacts with professionals. Governments should earmark resources for such outreach actions, and for assessing their effectiveness.
- Actions need to engage all persons who are concerned by declining interest in science. A network of stakeholders (linking educational resource centres, the business community, S&T education specialists, and student and teacher communities), should be established to share information on best practices between countries and the various communities involved.
- Curricula need to be more flexible to offer a second chance to students who wish to come back to S&T studies following a different choice at an earlier stage. Providing such an opportunity has a proven effectiveness, with excellent success rates when studies are resumed. Positive incentives (such as grants or guaranteed access to university), can make the scheme more attractive.
- Curricula should be redesigned to better reflect the reality of modern science and technology, and to emphasise their contributions to society. Specific actions can focus on encounters with S&T professionals, exposure to cutting-edge science and technology and their applications in modern life, debates on the role and social relevance of S&T, and actions directed towards a "humanisation" of science teaching. Teaching should

also concentrate more on scientific concepts and methods rather than on retaining information only. These goals are particularly important in secondary education.

- Professional skills and cross-disciplinary studies should be promoted in higher S&T education. Over-specialisation and the lack of elements of social dimension in the curriculum can deter some groups of students from pursuing tertiary S&T studies. In addition, skills such as communication, project management or teamwork are also increasingly valued in S&T careers. New programmes with an enlarged vision of S&T have proved to be more attractive to many students, especially young women.
- Incentives and resources must be provided to teachers who need training or refresher courses in S&T. These should be offered as part of a flexible framework of life-long learning. Teachers who make the effort to upgrade their skills and knowledge should be rewarded. This does not have to be financial – it could take the form of sabbatical leave for example. Specific initial training should also be provided, to raise the teacher's awareness of stereotypes that can be unconsciously transmitted to pupils, and particularly to female and minority students. Rewards should also be provided to teachers and academics who invest their time in S&T communication.
- Networks of teachers, from primary to university level, should be set up by teachers' associations and education ministries to share information on requirements and teaching practices in S&T studies. Although the context differs according to level of education, there are common features and lessons that should be discussed and shared among teacher communities.

The quantitative analysis has certain limitations

The quantitative study encountered significant limitations and obstacles, largely because it relied on specific national data sets. Ideally, an optimal analysis of student numbers would be based on complete sets of homogeneous data, in which countries would apply identical (or very similar), definitions of diplomas, educational levels, student categorisations, etc. Moreover, these definitions would be stable over time. Since this is not the case, the analysis was often limited to comparisons of trends and ratios, rather than of absolute numbers. Extrapolating student interest in specific disciplines from numbers of students in S&T studies must also be done with caution, as the relationships among numbers, choices, and the degree of interest in S&T studies are complex and indirect.

Heterogeneity in data sets limits the interpretations and may lead to conflicting conclusions

The statistics used in this study are not satisfactory for an exhaustive in-depth analysis of the situation at an international level. Few countries were able to provide the complete information set requested, principally because of changes in classification, or unavailability of breakdowns by scientific discipline. This was particularly the case for upper secondary graduates.

Despite the existence of the ISCED classification system for the various disciplines (revised in 1997), many countries do not have homogeneous data. Not all countries compile data using the ISCED definitions, and those that do sometimes interpret them differently (and even change these interpretations over time). These discrepancies make analyses of absolute numbers unreliable, particularly since graduates are sometimes double-counted, as the indicators cover the total number of graduations in a year, rather than the number

of persons graduating (some students get more than one diploma in a year). This can result in overstated total numbers or growth rates. It is also difficult to compare the evolution of specific disciplines between countries, and the analysis of trends over the years for various categories of students suffers from discontinuities. A similar situation exists for "foreign" or "minority" student categories.

Enrolment data do not necessarily reflect student interest or motivation

The quantitative study analyses trends in the number of students studying S&T subjects, but this is not necessarily a complete measure of the possible decline in the number of students interested in S&T studies. For instance, as S&T are prestige subjects, a decline in interest may not translate immediately into a decline in enrolment if the number of S&T places is limited. There may still be more than enough applicants with the necessary qualifications for the number of places available, even though the actual number of applicants is declining. Thus, a decline in the number of people wanting to study science may not result in an actual decline in enrolments. For this reason, the decline in interest in science studies may be stronger in some cases than that recorded in enrolments. Motivation surveys, which measure the actual interest of young people in various fields of study or the reasons behind their choice, are usually conducted as one-off studies, or (as in PISA), repeated at very long intervals. These studies, while providing important qualitative information, do not permit adequate quantitative assessment of interest or motivation.

Recommendations

- The consistency, significance, scope and coverage of quantitative indicators are being improved under the aegis of INES work (Indicators of National Education Systems). This endeavour should be further encouraged. To correctly evaluate trends, countries should make strong efforts, at international level, to measure the same elements that correspond to specific indicators. For example, there is a need for a clear distinction between numbers of graduations/diplomas and of graduate students, or a better definition of "foreign students". The new ISCED definitions used in education statistics are extremely valuable, but further improvements could be made, for example finer distinctions between science and engineering, or taking into account hybrid disciplines (such as biomedical engineering). Such measures would help countries that do not yet have statistical information by field of study to undertake such data gathering. Better metadata and specific data on new entrants should be compiled.
- New entrant and graduation data alone are insufficient for monitoring student interest in S&T studies. Such information is nevertheless very important, not only to analyse the phenomenon itself, but also to measure the efficacy of any new policies. Appropriate analytical models and indicators should therefore be defined at international level. These could be linked, for example, to analysing the number of candidates for S&T study positions and/or academic levels rather than just enrolment figures (in countries that apply a selective entrance examination to universities); measuring drop-out and switch rates; and acquiring information on the choices made by the best students (who traditionally chose S&T disciplines). International surveys (such as PISA or ROSE), that include questions on student motivation should do so over long periods, to make trend analyses possible.

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ANNEX A

Glossary of ISCED-97 Classifications and Disciplines

The old classification (ISCED-76), which applied to enrolments and graduates before 1998, is indicated in parenthesis if is it different from the revised version:

ISCED 0 Preceding first level (pre-primary).

ISCED 1 First level (primary).

ISCED 2 Lower secondary (2A, 2B, 2C). Generally continues the basic programmes of the primary level, although teaching is typically more subject-focused, often employing more specialised teachers who conduct classes in their field of specialisation:

- 2A Programmes designed to prepare students for direct access to level 3 in a sequence which would ultimately lead to tertiary education, that is, entrance to ISCED 3A or 3B.
- 2B Programmes designed to prepare students for direct access to programmes at level 3C.
- 2C Programmes primarily designed for direct access to the labour market at the end of this level (sometimes referred to as "terminal" programmes).

ISCED 3 Upper secondary level of education (3A, 3B, 3C). The final stage of secondary education in most countries. Instruction is often more organised along subject-matter lines than at ISCED level 2 and teachers typically need to have a higher level, or more subject-specific, qualification that at ISCED 2. There are substantial differences in the typical duration of ISCED 3 programmes both across and between countries, typically ranging from 2 to 5 years of schooling.

- 3A Programmes are designed to provide direct access to ISCED 5A.
- 3B Programmes are designed to provide direct access to ISCED 5B.
- 3C Programmes are designed to lead directly to ISCED 5A or 5B. These programmes lead directly to labour market, ISCED 4 programmes or other ISCED 3 programmes.

ISCED 4 (before 1998 included in ISCED 3 or 5). Post-secondary, non-tertiary education (4A, 4B, 4C) These programmes straddle the boundary between upper secondary and post-secondary education, even though they might be considered as upper secondary or post-secondary programmes in a national context. These programmes are often not significantly more advanced than programmes at ISCED 3 but they serve to broaden the knowledge of participants who have already completed a programme at level 3. The students are typically older than those in ISCED 3 programmes. They typically have a full-time equivalent duration of between 6 months and 2 years.

- 4A Programmes are designed to provide direct access to ISCED 5A.
- 4B programmes are designed to provide direct access to ISCED 5B.

- 4C Programmes are not designed to lead directly to ISCED 5A or 5B. These programmes lead directly to labour market or other ISCED 4 programmes.

Tertiary programmes are sub-classified into ISCED 5A, ISCED 5B and ISCED 6 programmes:

ISCED 5A Programmes are largely theory-based and are designed to provide sufficient qualifications for entry to advanced research programmes and professions with high skill requirements, such as medicine, dentistry or architecture. Tertiary-type A programmes have a minimum cumulative theoretical duration (at tertiary level) of three years' full-time equivalent, although they typically last four or more years. These programmes are not exclusively offered at universities. Conversely, not all programmes nationally recognized as university programmes fulfil the criteria to be classified as tertiary-type A.

ISCED 5B Programmes are typically shorter than those of ISCED 5A and focus on practical, technical or occupational skills for direct entry into the labour market, although some theoretical foundations may be covered in the respective programmes. They have a minimum duration of two years full-time equivalent at the tertiary level.

ISCED 6 programmes lead to the award of an advanced research qualification. The programmes are devoted to advanced study and original research. They require the submission of a thesis or dissertation of publishable quality that is the product of original research and represents a significant contribution to knowledge. They are not solely based on course-work and prepare recipients for faculty posts in institutions offering ISCED 5A programmes, as well as research posts in government and industry.

It should be noted that we chose to include and aggregate both academic (ISCED A) and vocational studies (ISCED B) in our analysis.

Disciplines

Our definition of science disciplines covers:

- Life sciences (No. 42 in the ISCED 1997 categories). This includes: biology, botany, bacteriology, toxicology, microbiology, zoology, entomology, ornithology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences.
- Physical sciences (No. 44 in the ISCED 1997 categories). This includes: astronomy and space sciences, physics, other allied subjects, chemistry, other allied subjects, geology, geophysics, mineralogy, physical anthropology, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, marine science, vulcanology, palaeoecology.
- Mathematics and statistics (No. 46 in the ISCED 1997 categories). This Includes: mathematics, operations research, numerical analysis, actuarial science, statistics and other allied fields.
- Computing (No. 48 in the ISCED 1997 categories). This includes: system design, computer programming, data processing, networks, operating systems software development (hardware development should be classified with engineering).

Our definition of Technology disciplines covers:

- Engineering and engineering trades (No. 52 in the ISCED 1997 categories). This includes engineering drawing, mechanics, metal work, electricity, electronics, telecommunications, energy and chemical engineering, vehicle maintenance, surveying.

- Manufacturing and processing (No. 54 in the ISCED 1997 categories). This includes: food and drink processing, textiles, clothes, footwear, leather, materials (wood, paper, plastic, glass, etc.), mining and extraction.
- Architecture and building (No. 58 in the ISCED 1997 categories). This includes: architecture and town planning: structural architecture, landscape architecture, community planning, cartography; building, construction; civil engineering.

ANNEX B

Survey "Attractiveness of S&T Studies and Careers"

Introduction

This survey was carried out by the Board of European Students of Technology (BEST) in September-October 2005. The results were presented at the the international conference organised by the the OECD Global Science Forum and the Netherlands Ministry of Education, Culture and Science on 14-15 November 2005, in Amsterdam.The objective was to present the students' point of view on the issue, supported by the outcomes of a survey on the "Attractiveness of Science and Technology studies and careers", whose results are analysed below. The questionnaire and its analysis were devised by Nicolò Wojewoda, BEST Educational Committee co-ordinator 2005-2006, with help from Susan Langer and Rudolf Mayer.

Methodology

On the 8th September 2005, a questionnaire was put online on *http://private.best.eu.org/*, a portal accessible to BEST members only, and promoted through the internal virtual communication tools of the organisation (mailing lists and web news). The submission of answers to the survey ended on the 22 October 2005.

The target base of the questionnaire were the members of BEST: university (or equivalent) students coming from different social and economic backgrounds, and with different nationalities (the BEST network currently covers 23 European countries). The number of BEST members is estimated to be around 2 000. BEST members were required to answer a series of questions related to their background, career and studies in S&T, factors related to their choice of study, and whether they had or wished to pursue a Ph.D. 265 answers were registered. More than 2/3 or the respondents were male students.

Most of them were between 20 and 25 year-olds, with peaks at 22 and 23.

Almost all European countries were covered, with a high level of responsiveness from Mediterranean countries such as Portugal (42 answers), Spain (33), Italy (20) and Greece (19), and by Romania (22). *Respondents were mainly undertaking either electrical engineering or computer science* studies (more than 40% of the answers came from both of them combined). Students from other fields were less representated: biology (1.6%), chemistry (5.9%), mathematics (1.6%) and physics (5.1%).Almost one out of two respondents (43.5%) had a father working in the S&T field, while only 24.9% had a mother working in S&T. Most of the respondents were between their third and sixth year of studies, in the middle of their study career.

Figure B.1. **Field of study**

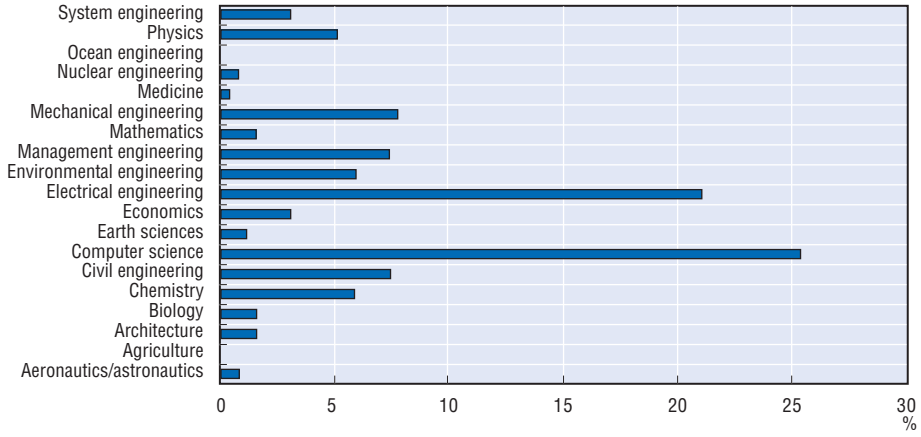


Figure B.2. **When did you choose S&T?**

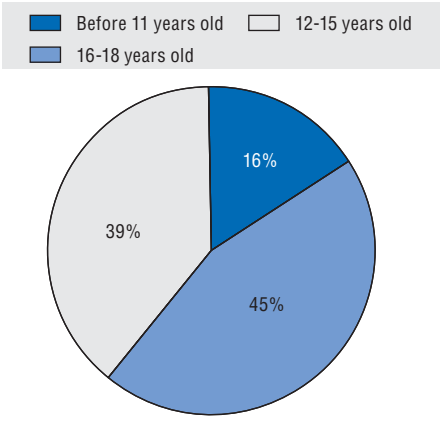
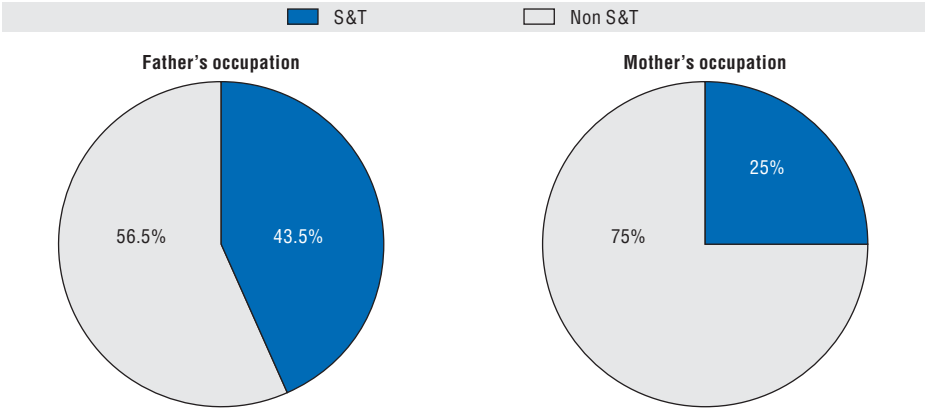


Figure B.3. **Father's occupation/mother's occupation**



Analysis of results

S&T as first choice

Almost all the respondents had S&T studies as their first choice, either at upper secondary level (88.2%) or at university level (94.3%). In the cases where their first choice

was not S&T, business/economics studies were predominant (17.8% at upper secondary level and 33.3% at university level) among other options.

Why are students attracted by S&T?

Almost all the students (96.9%, including 62.4% "very important" and 34.5% "important") consider the general interest in the topic as the first and most important factor in choosing to undertake S&T studies.

Then, career-related elements play a fundamental role in the choice. Almost as motivating as interest (54.3% "very important" + 37.8% "important" = 92.1%) is the chance of getting a job with an S&T diploma. Also, the possibiliy of changing jobs with an S&T degree is considered as important, or very important by 77.4% of the respondents. Education-related elements, such as the reputation of the university or the quality of S&T courses at particular university, score high percentages in the importance ranking, with percentages of around 80% for the "important" and "very important" answers combined.

On the same levels, socially-related factors, such as the knowledge of S&T professions (32% + 45.8% = 77.8%) and recommendation/support from the family (30.7% + 44.5% = 75.2%) also have a strong influence on the choice of students.

Figure B.4. **Main factors in choosing S&T studies**

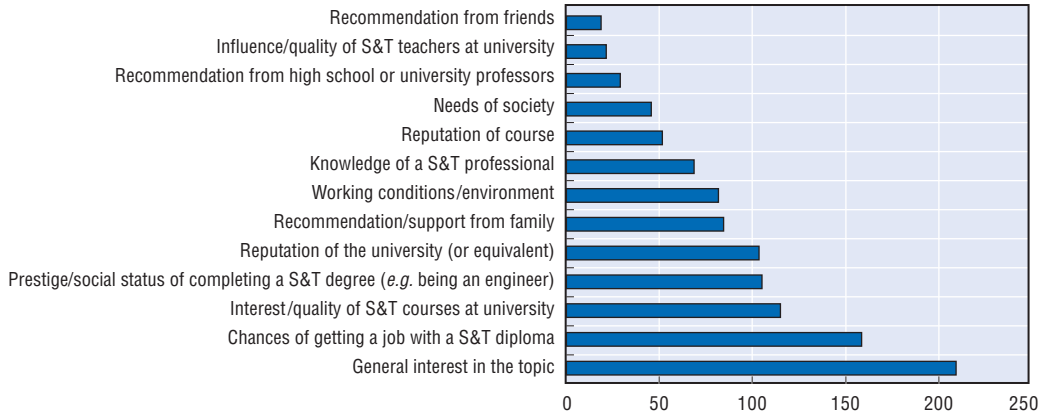
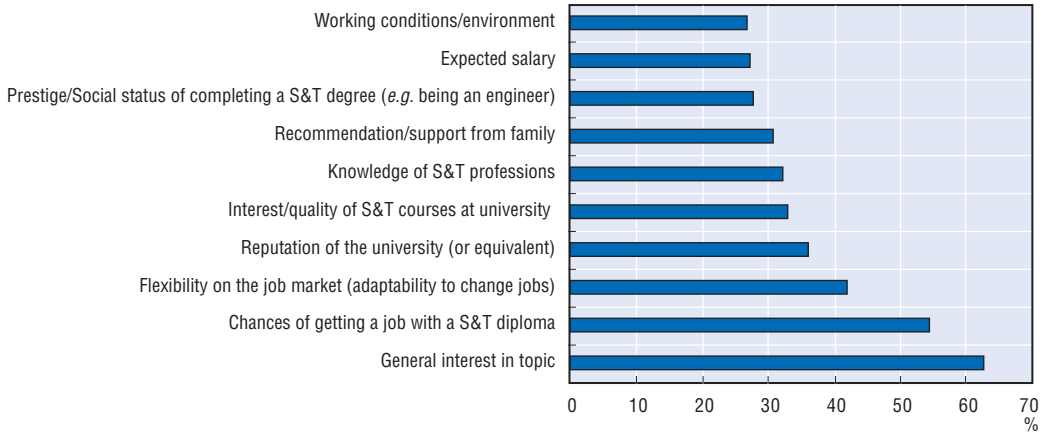


Figure B.5. **Top 10 factors in choosing S&T**



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What are the negative factors in deterring them to undertake such studies?

S&T studies are still perceived as difficult and demanding in terms of workload. These factors are considered important or very important by almost one third of the respondents, another third considers them of medium importance, and the other third thinks they are unimportant.

The low numbers of female S&T students is considered an obstacle, as well as the cost of S&T education (third and fourth factors in the ranking). The image and social status of a S&T professional ranks only seventh in the most negative factors list.

Figure B.6. **Most negative features of studying S&T**

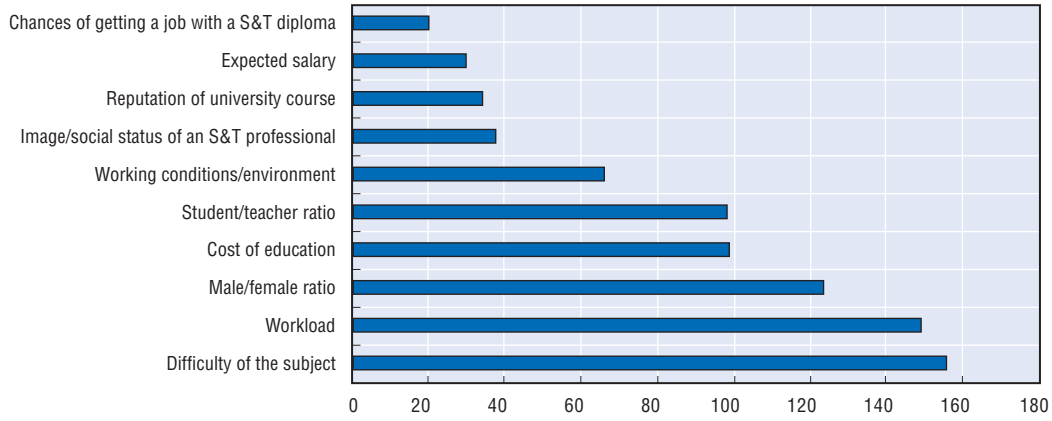
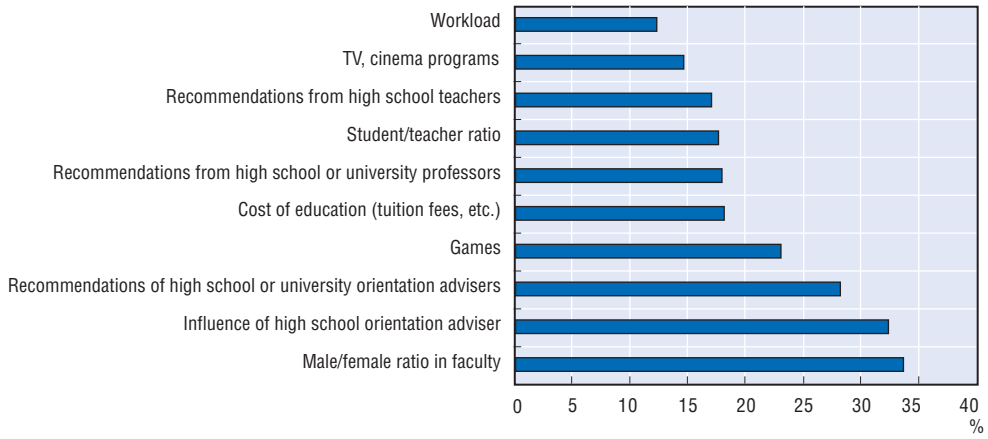


Figure B.7. **Factors considered most irrelevent in choosing S&T**



PhD studies

The primary reason for pursuing a PhD career, for both the ones who are already studying as PhD students and the ones who are not, is the interest in the topic (very important for almost 70% of the respondents).

Non-Ph.D student respondents are concerned about the quality of the PhD program (52.5% + 36.8% = 89.3 consider it as important or more), whereas such issues disappear for Ph.D students.

The interest in research scores high on both types of students, and, on the opposite, the interest in teaching scores low on both kinds of respondents.

The chances to find a job increase in importance when actually entering PhD studies. The "very important" answer rates at 32.4% for non-PhD students and at 45% among PhD students.

The needs of society are the least motivating factor (8.5% + 28.7% = 37.2%) in non-PhD students, whereas they turn out to be pretty motivating among PhD students (25% + 20% = 45%).

The case is similar for the prestige and social status of completing a PhD degree, going from average ratings (17.8% + 39.1% = 56.9%) among non-PhD students, to high ratings (30% + 55% = 85%) among PhD students.

Among the elements that deter students from undertaking PhD studies, the "need to get a job" (30.3% + 38.2% = 68.5%) is the most important one. Low quality of PhD programs, low added-value to the studies and not being interested in deepening the knowledge of the subject and doing research score similar values (22 to 27% + 32 to 39% = 54 to 66%).

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Encouraging Student Interest in Science and Technology Studies

An understanding of science and technology is necessary for those whose career depends on it directly of course, but also for any citizen who wishes to make informed choices about many controversial issues being debated today. A strong S&T base is vital for the economy too, as research and innovation increasingly decide the winners and losers in international competition for jobs and markets. Recently, a number of countries have expressed the fear that interest in S&T is declining, even as demand for S&T graduates grows. The Global Science Forum was asked to investigate whether this decline was really happening, and to analyse the reasons for students' choice of study and career as well as possible actions to encourage student interest in S&T studies.

Encouraging Student Interest in Science and Technology Studies examines overall trends in higher education enrolments and the evolution of S&T compared with other disciplines. The results suggest that although absolute numbers of S&T students have been rising as access to higher levels of education expands in OECD economies, the relative share of S&T students among the overall student population has been falling.

The report shows that encouraging interest in S&T studies requires action to tackle a host of issues inside and outside the education system, ranging from teacher training and curriculum design to improving the image of S&T careers. Numerous examples of national initiatives are used to complement the analyses to derive a set of practical recommendations.

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