OCDE Global Science Forum

DECLINING ENROLMENT IN S&T STUDIES:

IS IT REAL?

WHAT ARE THE CAUSES?

WHAT CAN BE DONE?

Working document

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SUMMARY

The apparent decline in student enrolments in science and technology at various levels of the educational system is viewed with concern by many OECD countries, and the Global Science Forum authorized an activity on the issue at its Ninth Meeting in July 2003. This issue was then also highlighted during the ministerial meeting of the OECD Committee for Scientific and Technological Policy in January 2004 as a priority for the OECD Secretariat, in the context of the more general problem of human resources in science and technology. This GSF activity is therefore taking place within a more general framework of projects within the OECD.

Following the conclusions of a Steering Committee, chaired by Prof. Jean-Jacques Duby from 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. Statistical data on student enrolments and graduations has been submitted by 18 countries and analysed together with information on both causes and solutions of the decline and recommendation are being drawn up.

The Working Group results and recommendations will be presented and debated during the concluding conference co-organised by the OECD Global Science Forum and the Ministry for Education, Culture and Science of the Netherlands in Amsterdam on November 14/15, 2005.

The final report on the entire GSF activity (which will take into account the results of the conference) will be ready in early 2006.

Participation

Working Group members were nominated by the seventeen delegations of Australia, Belgium, Canada, Denmark, the European Commission, Finland, France, Germany, Ireland, Italy, Japan, Korea, the Netherlands, Norway, Portugal, Sweden and the United States. Prof. Sjoerd Wendelaar Bonga of the Netherlands has served as chairman.

Scope of the activity

The Working Group has examined three main aspects of the problem:

1. Define the actual extent of the problem through a quantitative analysis of the statistical data
2. Analyse the contributing factors, focusing particularly on early stages of the educational process
3. Review the solutions that may have been implemented and draw up recommendations

What this Working Group **did not** address is the potential impact of the decline on national economies and on society in general or the relationships between supply and demand for S&T students.

Main findings

1. A long-term trend of declining student enrolment in S&T courses that hides important disparities

The statistical data gathered in this study regroup not only information on the number of graduates and Ph.Ds in S&T, but also on secondary level/high school diplomas and enrolment in tertiary education in S&T-related fields. When available, the data were also analysed by gender and by national/foreign origin.

Important discrepancies between national data terminologies prevented most detailed comparative analyses of absolute numbers. However, the main objective of this study was to analyse long-term general trends which are presented.

A general decline in S&T students in relative terms

In most countries, the absolute number of S&T students over the analysed period has increased. This is largely due to the growing enrolment rate in tertiary education in OECD countries. However, the relative proportion of S&T students has declined in recent years (Figure 1), particularly since the mid-90s. This is true not only in tertiary education but also for upper secondary graduates. Coupled with an unfavourable demographic evolution, several OECD countries can expect this general trend to continue in future years, although some recovery may be detected in very recent years in some countries.

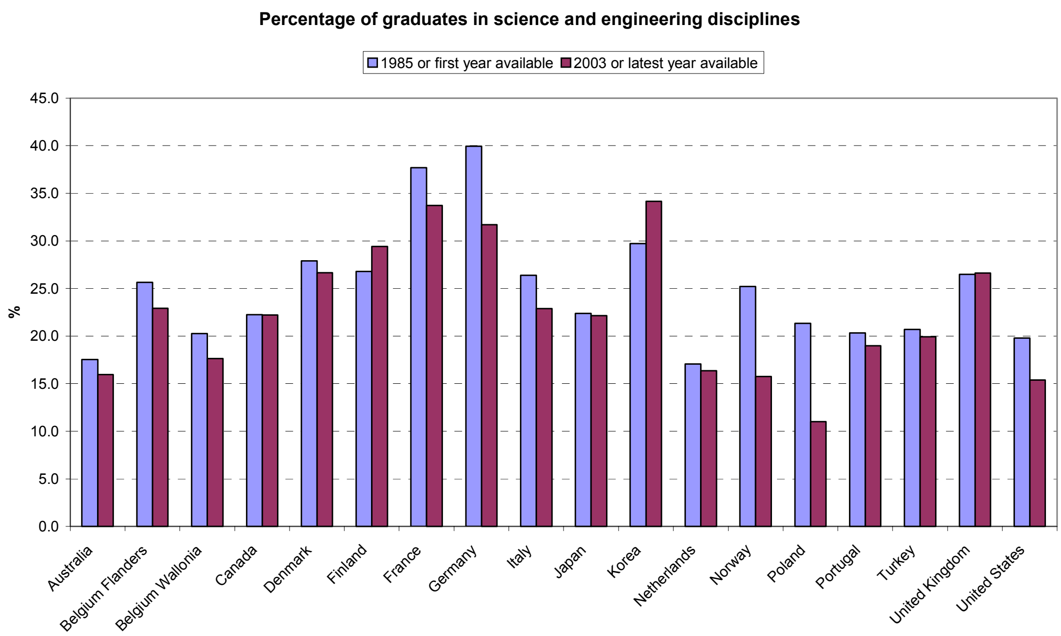


Figure 1

All countries do not face similar problems

While the data clearly show a declining trend for some countries, this is largely offset in other countries by a still rapidly growing population of students, while a limited number of countries have managed to keep a positive growth of their proportion of S&T students.

S&T disciplines are differently affected

Physical sciences and mathematics are the worst hit by the decline (Figure 2). For these fields, the decline is often seen for the absolute number of students. In some countries, the proportion of students in such fields may have been halved between 1995 and 2003. On the other hand, the proportion of students in life sciences and engineering has remained mostly stable (due to an increase of female students in life science and of a growing interest for vocational studies in engineering), while the number of computer sciences students has exploded.

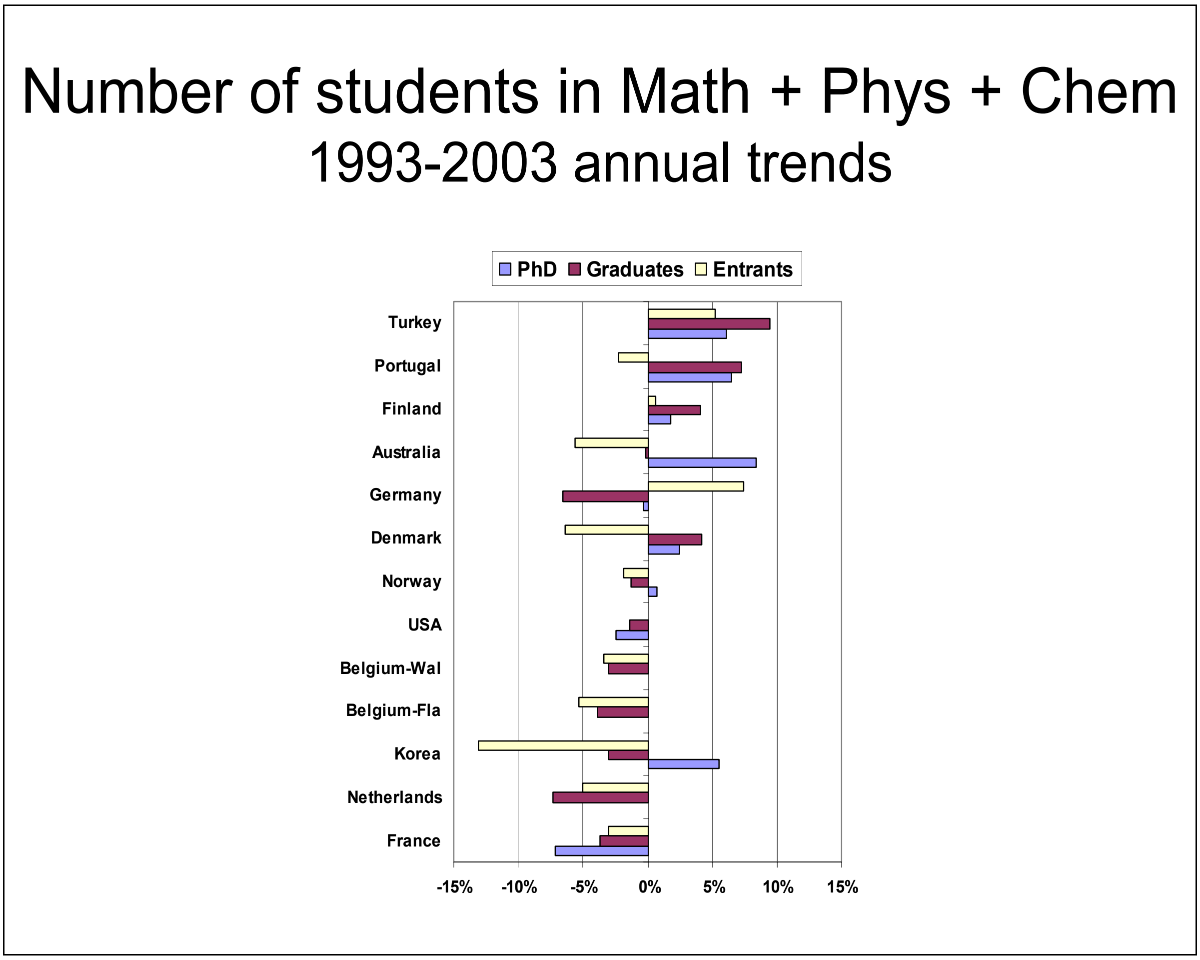


Figure 2

<u>The share of women in S&T studies is increasing, but has not yet caught up to that of men</u>

The number of girls in tertiary education has increased more rapidly than that of boys. Nevertheless, the proportion of girls choosing S&T studies has not reached that of boys. Furthermore, even if that 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 student graduates in S&T may hit a maximal 40% “glass ceiling” even in the most “effective” countries, maybe due to a selective choice of girls for some specific fields. For instance, women are systematically more numerous than men in life sciences (Figure 3). The choice of disciplines is very much differentiated according to gender.

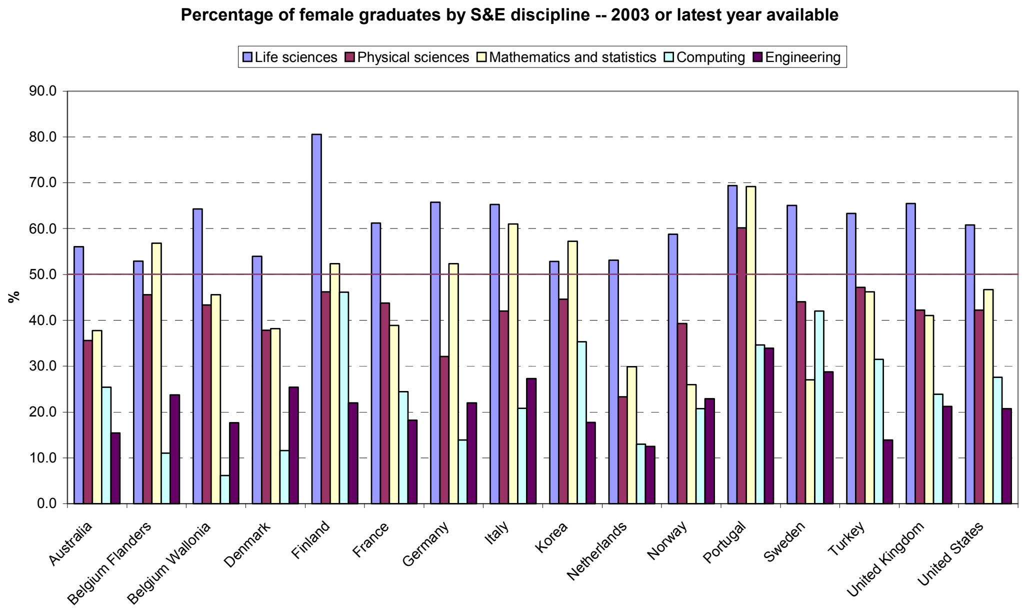


Figure 3

<u>The proportion of foreign students in S&T remains low except at Ph.D level</u>

The share of foreign S&T students has increased in most countries but rarely exceeds 5-10% except for Ph.Ds for which this proportion may be much higher and could help slow down the decline in S&T students.

2. A broad variety of contributing factors

Many factors have been cited as being responsible for a growing lack of interest of young students for S&T studies. In this study, these factors were grouped in five categories for analysis:

1. Image of science and technology and S&T professionals
2. Science and technology careers
3. Science and Technology education and curricula
4. Teacher training, qualification and development
5. Issues related to gender and ethnic/cultural minorities

A special emphasis was put on the early stages of the process, when actions may have higher and longer lasting impact (actions on “intrinsic” motivations are often more efficient than on “extrinsic” motivations), and on the importance of the different key orientation steps within the educational process.

<u>A general context that has evolved since the mid-90s</u>

As summarised in Figure 4, the factors contributing to a possible decline in interest for S&T studies should be analysed within considerable changes in the general context: economical hardship, evolution of societal values, demographical changes, and a considerable expansion of educational opportunities. It is therefore not surprising that a shift in priorities and choices is being observed among students. On another hand, science and technology has also permeated many traditional fields of study and professions that now require such knowledge.

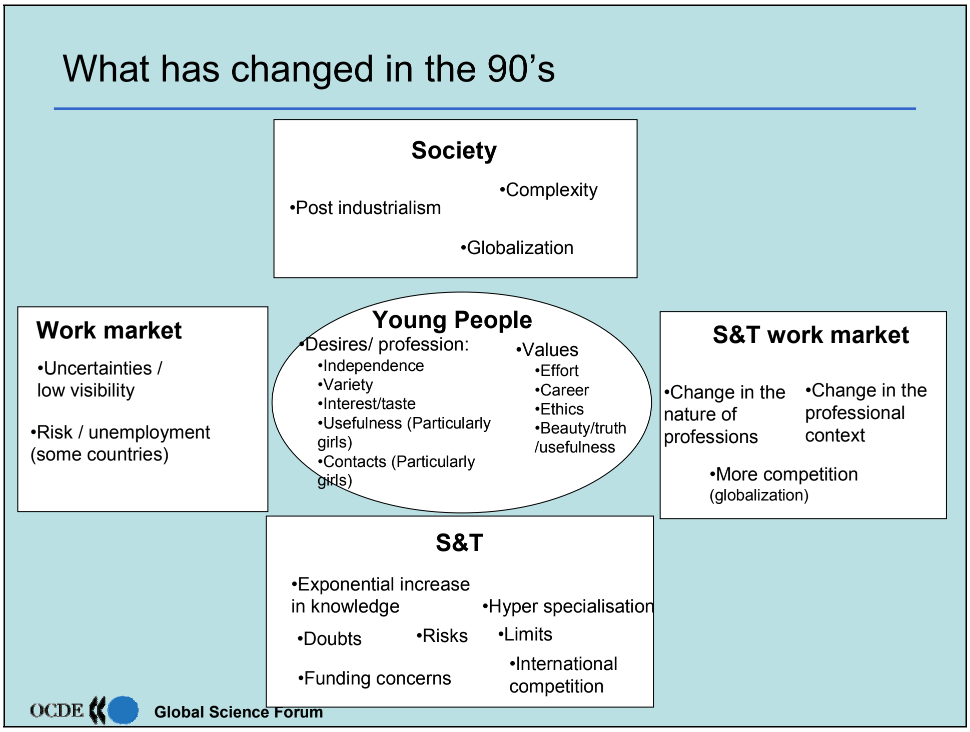


Figure 4

The image of science and scientists remains positive but S&T professions are less attractive

Image and motivation surveys show that the perception of science and technology remains largely positive among young people, with some exceptions. In addition, S&T careers are still a choice recommended by parents. However, the perception that young people have of these careers and of scientists' or engineers' lifestyles is not attractive to them. Incomes in S&T careers are often perceived as too low relative to the amount of work and difficulty of the studies required, pupils have a poor knowledge of science-related professions and are largely unaware of the range of career opportunities opened by S&T studies.

Poor opinions towards S&T studies (and dropping out) are often linked to negative pedagogical experience

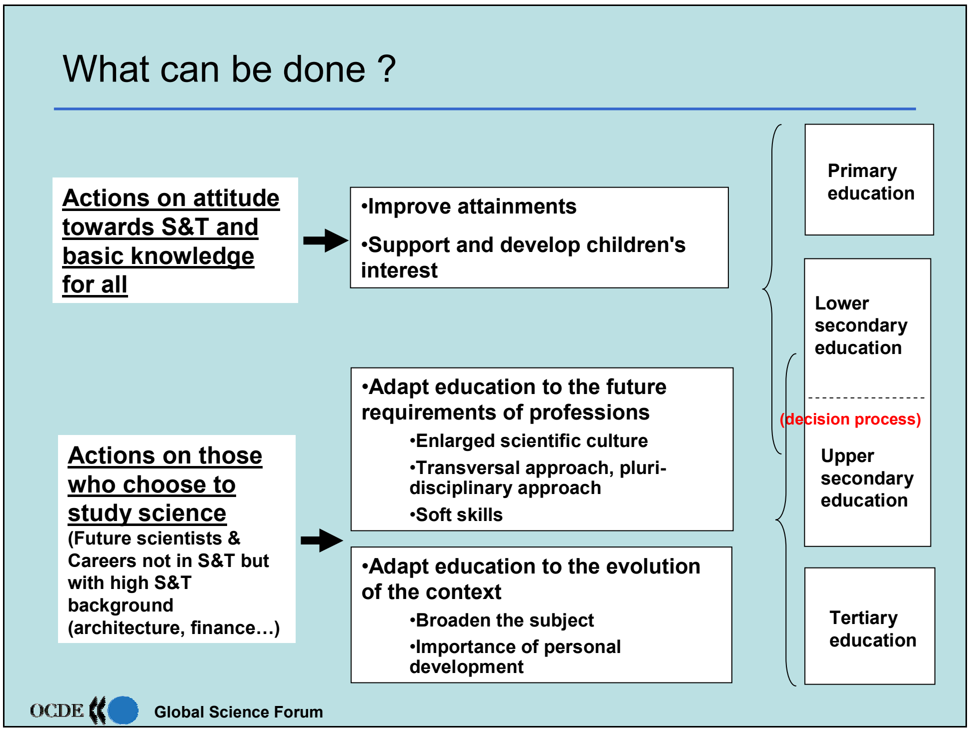
Children in primary school have a natural curiosity for science and technology, and can form at this stage a long-lasting interest for these issues. However, many primary teachers are not comfortable with science subjects and with hands-on situations, while teaching often focuses on knowledge and facts rather than on understanding. At lower secondary school level, pupils need to feel the relevance of the subject to their own world. What is taught is often disconnected from cutting edge science or from the recent applications of S&T and often annihilates the interest acquired at a younger age. At upper secondary and tertiary levels, S&T topics have to compete with new, trendier, subjects. Tertiary studies and future careers are often based upon their perceived interest ("passion/pleasure factor") by secondary school students. Moreover, the high drop out rates in S&T in some countries, in addition to mechanically reducing the number of S&T graduates, may deter young people from choosing these subjects.

Female and minority students are not encouraged to follow S&T studies

Female students, and students from various cultural or ethnic minorities, suffer from stereotypes in relation to external (parents, teacher, society…) expectations. They also lack role models (famous scientists, family members etc…) with whom they can identify, and may find themselves isolated in the homogeneous group formed by the majority of the other students studying S&T topics.

3. Existing solutions are rarely evaluated

A number of countries have initiated or are initiating action plans and other types of remedies to fight the S&T enrolment decline. These fall into two categories: "action plans" that include a large spectrum of actions at a wide level (nation or state) and "best practices" that are more specific actions focused on a reduced number of specific objectives and targets. However, very few of all these initiatives have been properly evaluated in terms of their impact on student enrolment in S&T subjects. In addition, many initiatives focus on a limited number of children and would be difficult to scale up.



Start young !

Interest in S&T appears during primary school, and longitudinal surveys show that this interest remains stable between the ages of 11 and 15. Such interest may have a strong influence on subject choices, but long-term impact of measures at this age are difficult to evaluate. Interesting measures target the teachers themselves (confidence and taste for S&T), teaching content (hands on experience), and the pupils (extracurricular activities, communication…).

Pay specific attention to the years around 15

This is the age at which interest towards S&T declines the most sharply, when gender differentiation starts to translate into choices, and a key period for future orientation. Specific actions can focus on meeting with real professionals, exposure to cutting-edge science and technology and their use in modern life, debates on the role and social relevance of S&T and all actions directed towards a “humanization” of science teaching.

Propose opportunities for students to come back into S&T track studies

Students have to make their first orientation choice usually at the age of 15-16. Those who, for various reasons, do not choose to follow S&T studies as their main subjects are often definitively excluded from these fields. Giving a second chance to 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.

Develop multi/trans-disciplinary courses and soft skills

Over-specialization and the lack of social knowledge are among the factors that can deter some groups of students from pursuing tertiary S&T studies. In addition, skills such as communication, project management or team work are also increasingly valued in S&T careers, similarly to non-S&T profession that now often requires S&T knowledge. New programmes with an enlarged vision of S&T have shown to be more attractive to many students, especially girls.

ACRONYMS

MSE/SME : Mathematics, Science and Engineering

S&T: Science and technology

S&E: Science and engineering, based on ISCED classification

STI: Science Technology and Industry

MST: Mathematics, Science and Technology

INTRODUCTION

This study is aimed at analysing the decline in young people interest towards science in OECD countries.

The background for the study is given in the first chapter. Then, the quantitative analysis is presented in the second chapter and is aimed at determining the extent of the phenomenon as well as its main characteristics. The third chapter relates to the reasons that could play a part in deterring young people from science studies while the fourth one is intended to present some remedies that have already been tried or are currently under implementation. The fifth chapter contains recommendations that could help setting up measures to reinforce young people's interest in science.

The choice for or against science studies is obviously a result of both rational and perceived elements. When available, rational elements are presented, but our main aim was not to find out the rational criteria and to answer the question whether young people are right or not to behave the way they do. Rather, it was to identify the key factors behind their choice, whether true or only based upon their perception of reality. Therefore, when young people's perception of science studies is mentioned, we will not examine if this perception is based on facts or not, since such perception in itself will have an impact on the actual choice.

PART ONE: BACKGROUND FOR THE STUDY

1. ORIGINS OF THE STUDY

The development of human resources in science and technology is an acknowledged priority for countries that seek to advance science and technology as major driving forces of the increasingly globalised economy. Observations suggest an apparent decline in interest in science and engineering studies in a number of OECD countries. This apparent decrease in student enrolment at various level of the educational system varies from country to country. It affects mathematics, physics and chemistry, and, to a lesser extent, the life sciences at both undergraduate and graduate levels, although this may be sometimes hidden by an influx of foreign students in some countries.

The actual effect of such phenomenon on the workforce has not been assessed precisely, but some countries report difficulty in recruiting properly trained students to fill vacancies for scientific jobs and are concerned about the impact on competitiveness and productivity.

Several reasons have been put forward to explain such a decline of interest in scientific studies. At the educational level, possible explanations include the lack of interest in science teaching, perceived difficulty of science courses, and traditional orientation of girls and of some ethnic minorities towards non-scientific curricula. Career aspects are also important as scientific careers both in public and private sectors may be perceived as less rewarding than finance or management for a similar investment. Finally, a general concern about negative public perception of science has emerged as distrust of science may influence education choices.

Faced with convergent studies, a number of countries have realised the importance of the problem and started to address it through policy recommendations and a variety of measures. Such initiatives are, however, often still in their infancy and little evaluation of their impact has been carried out. In addition, there has been little co-operation among OECD countries to confront their national situation and share evidence on the effectiveness of ad hoc solutions they have undertaken.

The Global Science Forum authorized an activity on the issue at its Ninth Meeting in July 2003. This issue was then also highlighted during the ministerial meetings of the OECD Committee for Scientific and Technological Policy in January 2004 and Education Committee in March 2004 as a priority for the OECD Secretariat, among the more general problem of human resources in science and technology, and this GSF activity is therefore taking place within a more general framework of projects within the OECD

2. OBJECTIVES

The objective of this work was to draw up recommendations that may help national governments to set up, if required, policies to increase the number of young people undertaking S&T studies. The analysis was therefore focused on the supply of S&T students only. The Working Group has examined three main aspects of the problem:

1. The actual extent of the problem, through a quantitative analysis of the statistical data.
2. The contributing factors, focusing particularly on early stages of the educational process.
3. The solutions that may have been implemented, to draw up policy recommendations.

What this Working Group did not address is the potential impact of a decline of interest for S&T studies among young people on national economies and on society in general or the relationships between supply and demand for S&T graduates.

3. PARTICIPANTS AND METHODOLOGY

- **The value coming from the WG composition : 30 experts from different countries**
- **the scope: our definition for S&T**
- **A choice to focus on early stages**

PART TWO: QUANTITATIVE ANALYSIS

1. INTRODUCTION AND METHODOLOGY

The objective of this chapter is to assess the amplitude and characteristics of the decline on the basis of solid data. To this aim a special data collection exercise was conducted with the help of the participating countries (see methodological box)

METHODOLOGY

The need for a specific collection of data derives from some limitations of the current international statistical system.

First, such data are available only at the tertiary level. If the Programme for International Student Assessment, 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 the 2006 PISA assessment will put the main focus on the knowledge, skills and attitudes of 15-year-olds towards science, the extent of the problem however needs to be gauged with solid data of the number of students choosing S&E studies.

Second, data by field of study are rather limited in detail and time span. The revision of the ISCED (International Standard Classification of Education) in 1997 has introduced a break in series by changing the definitions of educational levels and disciplines preventing analysis of trends over time.

The specificities of our data collection:

Series and period

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

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

Scope

In S&E, we chose to include life sciences, mathematics and statistics, physical sciences, computing sciences and engineering

We collected also the split between genders and nationality status (with two categories: citizens and foreigners)

The 18 countries for which data have been provided are: Australia, Belgium (Flanders + Wallonia), Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Norway, Poland, Portugal, Sweden, Turkey, United Kingdom, United States.

We chose to include and aggregate both academic (ISCED A) and vocational studies (ISCED B) in our analysis.

Limits

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. The international comparability of the data is therefore limited and the analysis is for this reason conducted in terms of trends and ratios and not in terms of level comparisons.

2. FINDINGS: OVERALL TRENDS

2.1. AN UNFAVOURABLE DEMOGRAPHIC SITUATION

2.1.1. Declining cohorts in most countries

Most countries within our scope experienced a significant decline in their 15-19 year-old population with only a few exceptions. (see figure 1)

This decrease has been continue over the period in the EU earlier member countries (15) while it has appeared more recently, in the early 90's, in Japan. Conversely, the demographic situation has continuously been improving in the US since the early 90's.

This negative trend has reversed upward in some countries in the very last years. This is for instance the case in the Netherlands, Norway, Portugal, Sweden and the United Kingdom

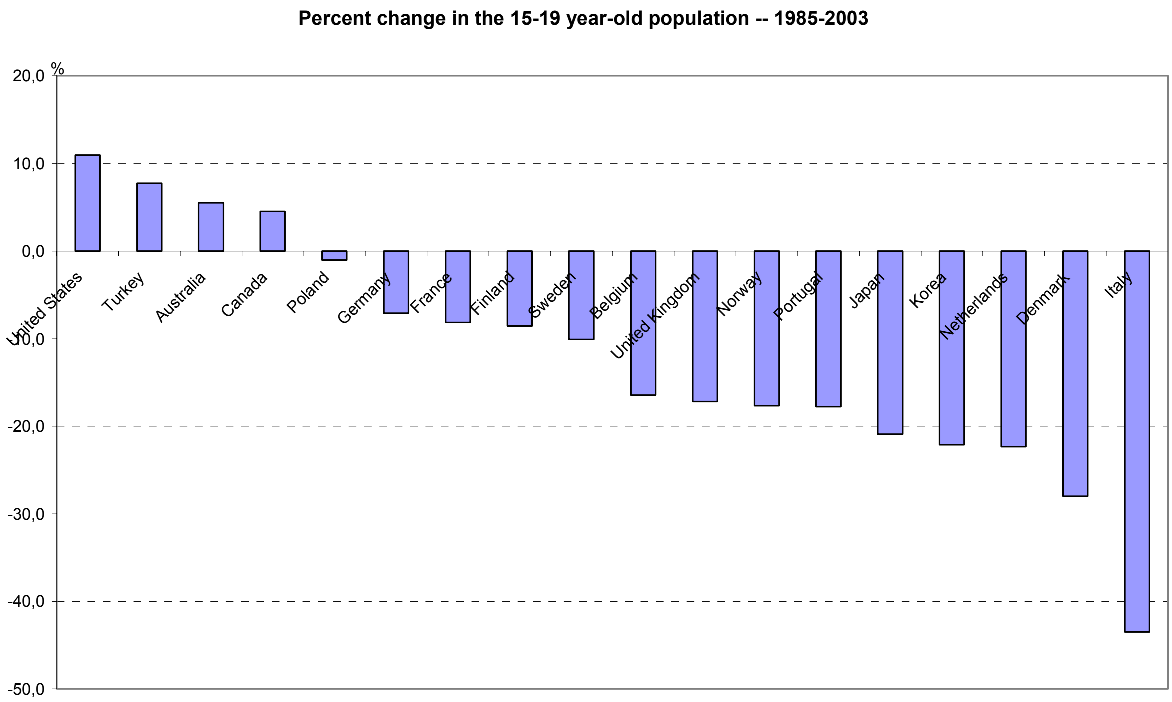


Figure 1.

2.1.2. Consequences on absolute numbers of upper secondary graduates

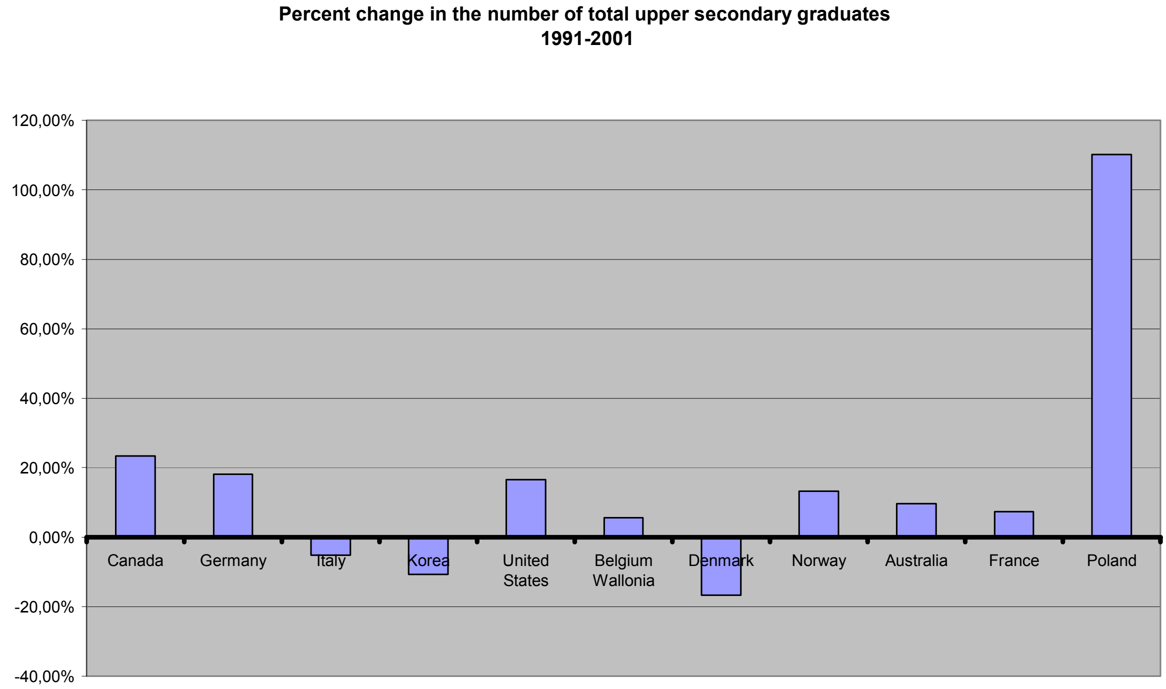


Figure 2.

The declining demographic trends have been counterbalanced to some extent by a better access to upper secondary education. As a result of these two opposite trends and contrary to what occurred in the previous periods, the number of upper secondary graduates was relatively stable or showed only moderate increase over the 91-01 period in most countries within our scope (see figure 2).

Poland is an exception to this scheme with a number of upper secondary graduates that has almost tripled between 1986 and 2002.

The situation for the **US** is also to be mentioned as their figures show specific pattern. They started declining in the late 80's and were low during the first half of the 90's, before the trend reversed in 1993 and continuously improved since then resulting in better figures at the end of the period than at its beginning (nearly 3 million in 2003 compared with 2.6 in 1985) .

Two other specific evolutions are worth mentioning even if not shown in the above chart. The first one refers to **France**, which upper secondary graduates number was multiplied by 1.7 between 1985 and 1995 but stabilised and slightly decreased since. The second one refers to **Korea** which has experienced a succession of up and down trends in the number of students enrolled at 12th grade resulting in an overall diminution by 22% between 1991 and 2003.

2.2. UPPER SECONDARY GRADUATES WITH A S&E ORIENTATION

2.2.1. Stable or declining shares

As said above in the methodological box, data on upper secondary graduates with an S&E orientation are not available for many countries.

Among the nine countries analyzed, the trend is either stable or in diminution, except for Korea, over the covered period. (see figure 3)

Percentage of upper secondary graduates with an S&E orientation

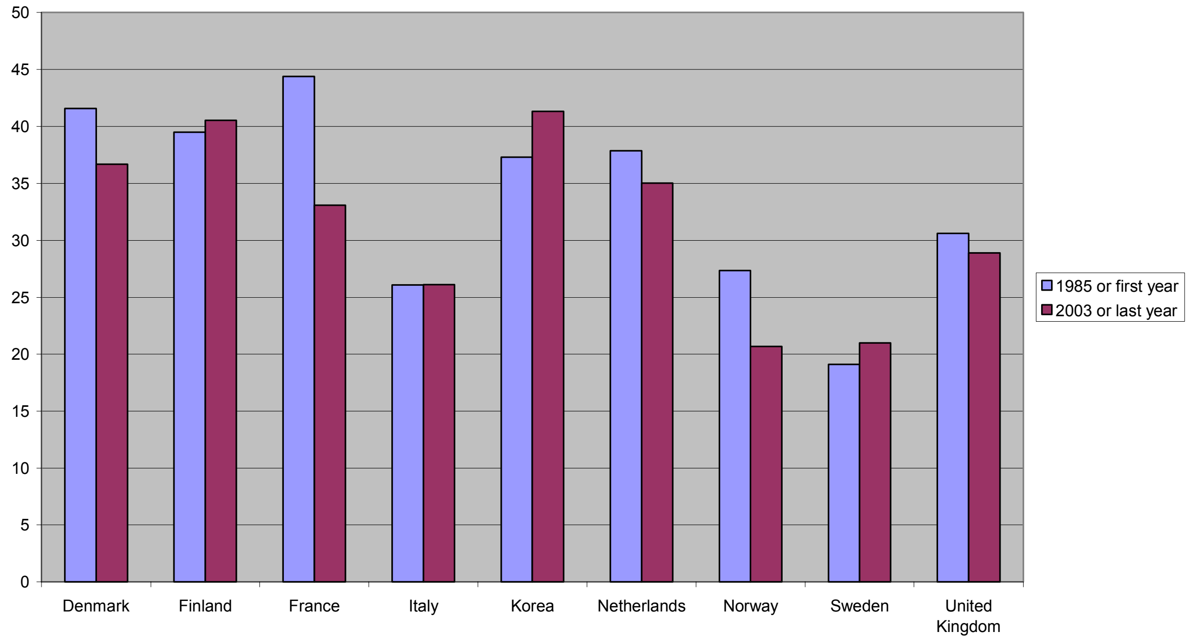


Figure 3.

The strongest decrease occurred in **France** from 44% at the beginning of the period to 33% at the end. This is mainly due to the strong increase of upper secondary graduates with other orientation than S&E (multiplied by 1.6 – see figure 4).

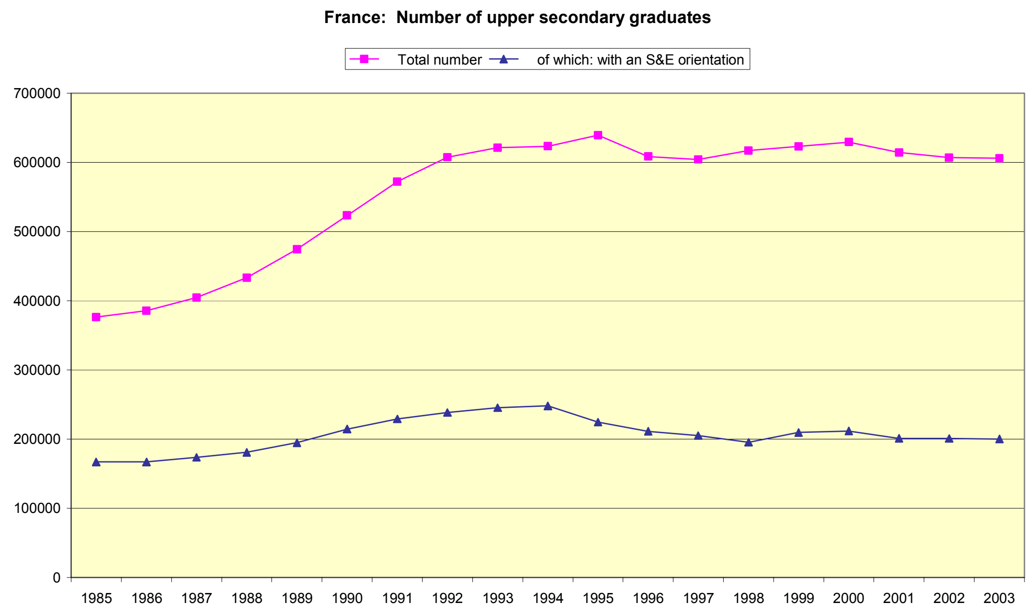


Figure 4.

Interestingly, the variation is primary due to that of young men who after multiplying their number by 1.2 from 1985 to 1996 have turned away from S&E oriented upper secondary paths by almost the same magnitude in the following period. The number of women choosing an S&E orientation has conversely increased over the whole period, but not in a proportion that can offset the reverse trend of male graduates, the latter still forming the large share of S&E baccaulauréats (68% in 2003).

Denmark is in a situation similar to many OECD countries where demographic trends display a decline in the number of young people at the age of upper secondary graduation. This trend is reflected in the total number of upper secondary graduates which, after increasing at the end of the 80's, has stabilised during the first half of the 90's and decreased by 17% from the beginning since 1995. The decline started even earlier among those graduates with an S&E orientation. Their share has lost 5% between 1985 and 2002 from 42% to 37%. Both men and women are affected, although half of men come out with an S&E orientation while only 27% of women do.

Korea experienced a moderate increase. It has to be noted that rates have increased till 1999 but decreased since then. The decline over the period has been more prominent for men than for women

2.3.GROWING ENROLMENT RATES IN TERTIARY EDUCATION

The global enrolment rates to tertiary education have increased over the period in all the countries within our scope. In most of them the increase is very significant. As a result, it has largely absorbed the negative or stable demographic trends. The result is a significant increase in the numbers of students in tertiary education, of over 30% in 10 countries out of the 19 within our scope. (see figure 5)

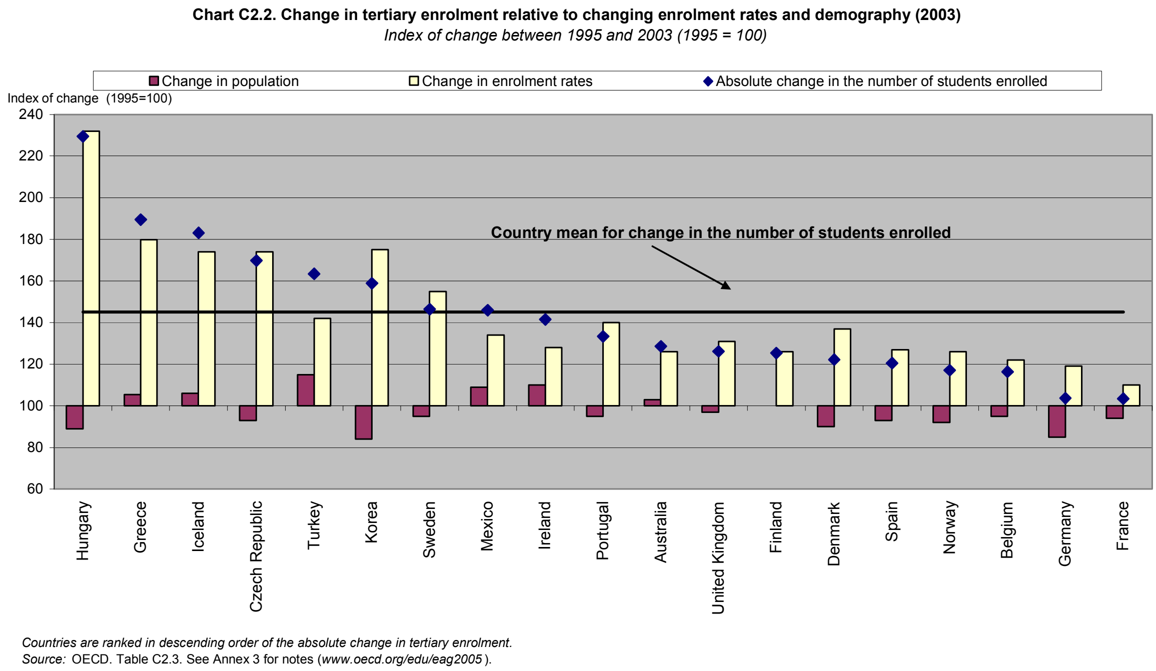


Figure 5.

2.4. ABSOLUTE NUMBERS IN S&E DISCIPLINES

As a consequence of the general increase in tertiary enrolment rates, absolute numbers at every level in S&E have generally increased over the 1993-2003 period (see figure 6).

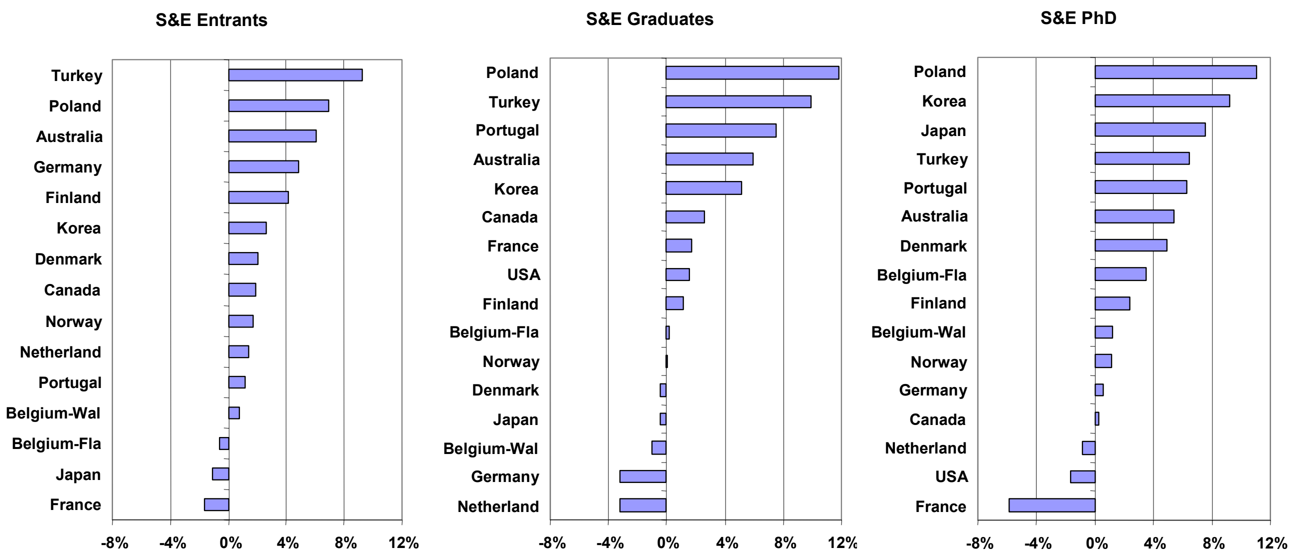


Figure 6.

Number of S&E students - 1993-2003 average annual change computed as Mean normalized regression coefficient

The number of **new entrants** in S&E disciplines has increased slowly but steadily over the 1985-2003 period. Japan numbers first increased strongly in the 80's but started decreasing in the early 90's, while in Germany the decrease in the early 90's has beeen followed by an increase.

Most countries have experienced a steady increase of the numbers of S&E **graduates** over the period. France has experience one of the strongest one with the numbers having more than doubled between 85 and 2003 but a reversed trend has followed since 1999, while Japan and Germany experienced a decline since mid-90's.

After a period of growing numbers of new doctorates, trends started to decline recently (late 90's) for the United States, France Canada and Germany.

2.5.S&E GRADUATES RELATIVE TO POPULATION AT THE AGE OF GRADUATION

The absolute numbers of S&E graduates per thousand 20-24 year-olds have generally increased over the period (see figure 7).

This is important as this indicator best reflects the share of people having been trained in S&E among the new entrants on the world market.

One of the most dramatic increases occurred in France, where the number of S&E graduates progressed from 27 to 56 per thousand 20-24 year-olds between 1985 and 1995.

This results from the very large increase in the total number of graduates per thousand 20-24 year olds (due both to the strong increase of upper secondary graduates at the end of the 80's and to their growing propensity to pursue in tertiary education,) even though the share of S&E graduates decreased from 31 to 27%.

Number of science and engineering graduates per thousand 20-24 years old population

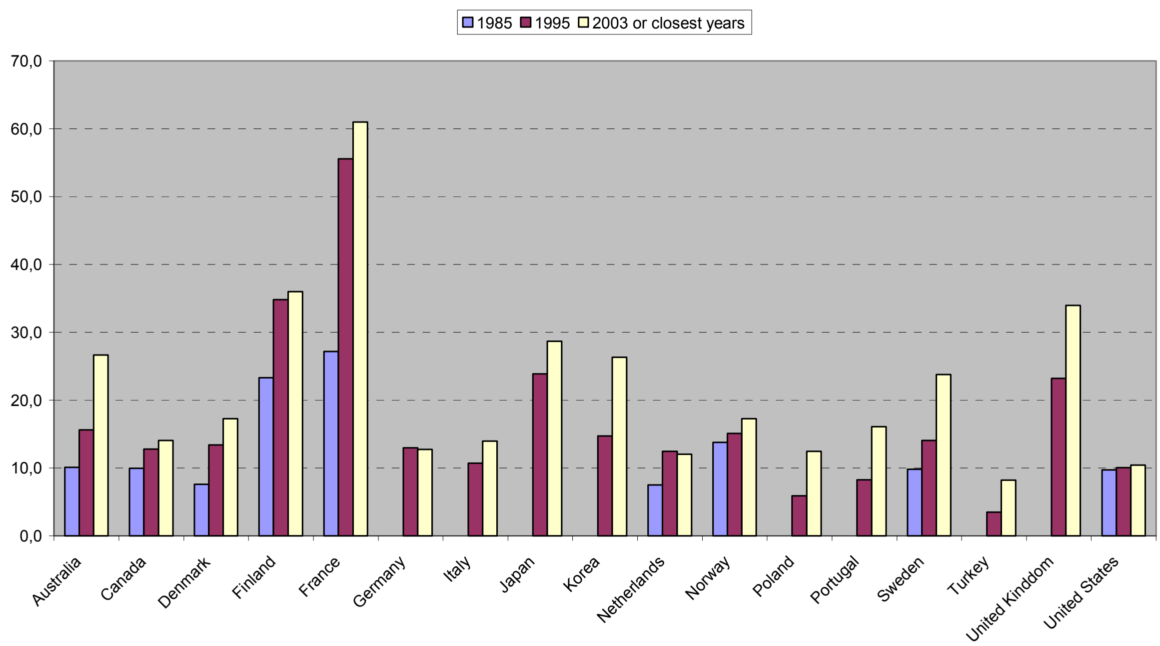


Figure 7.

CONCLUSION:

As a conclusion to this part on general context, the general trend is an overall increase over the 1985-2003 period in the absolute numbers of S&E students, as well as in the number of S&E student relative to the 20-24 year olds. As we will show in the following part, the overall trend may hide differences between more specific situations and there are nevertheless declining trends in relative terms, specific disciplines and over the last period.

3. FINDINGS: WHERE AND WHEN DECLINING TRENDS OCCUR?

3.1. PERCENTAGE OF S&E STUDENTS RELATIVE TO ALL STUDENTS

In proportion of all students, S&E students declined in many countries over the 1993-2003 period.

The trends are more negative at the higher levels.

The percentage of graduates in science and technology disciplines declined over the period in 10 countries out of 16 and the trends are even more negative at the doctorate levels with all countries showing negative trends except three of them (see figure 8).

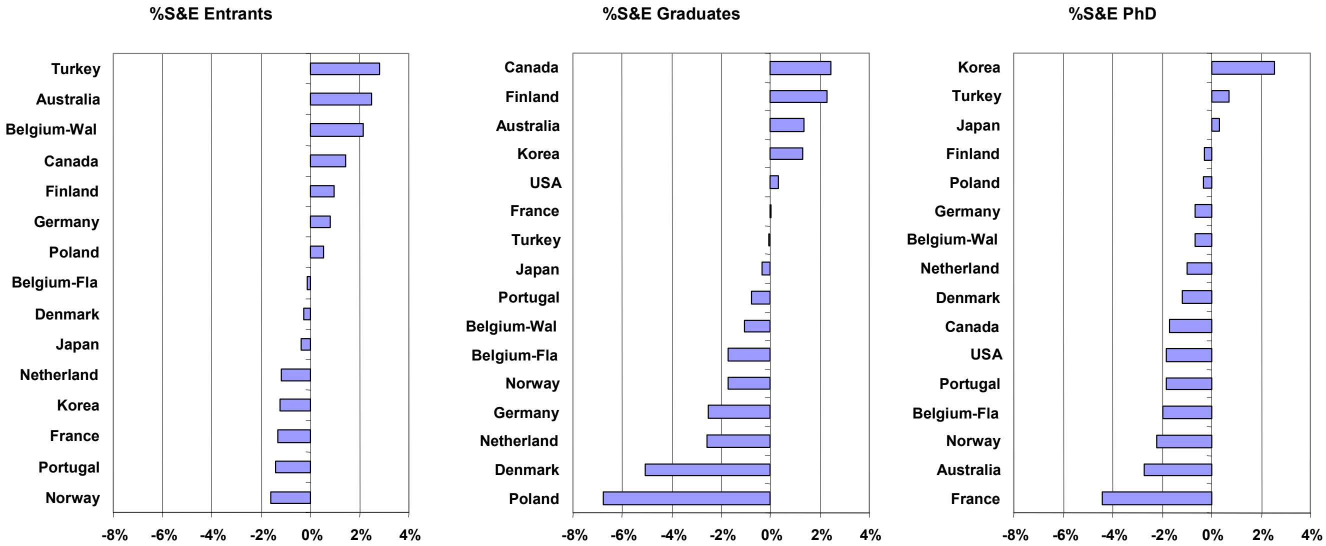


Figure 8.

Percentage of S&E students - 1993-2003 average annual change computed as Mean normalized regression coefficient

3.2. THE HIGH SHARE OF ENGINEERS MAY HIDE INDIVIDUAL DISCIPLINE TRENDS

Aggregate numbers hide differences among disciplines and some of these disciplines show a decline in the number of students even in absolute terms.

In most countries, engineering account for a significant share (between 40% and 60%) of the overall S&E students, especially at the new entrants and graduates level. And Engineering disciplines had more positive trends over the period than some scientific disciplines such as Mathematics and physics. Thus a contrasted situation results in overall positive aggregated numbers. (see figure 9).

Engineering, according to the ISCED definition, comprises engineering and engineering trades (engineering drawing, mechanics, metal work, electricity, electronics, telecommunications, energy and chemical engineering, vehicle maintenance, surveying), manufacturing and processing (food and drink processing, textiles, clothes, footwear, leather, materials such as wood, paper, plastic, glass, etc, mining and extraction), architecture and building (architecture and town planning, building construction, civil engineering)

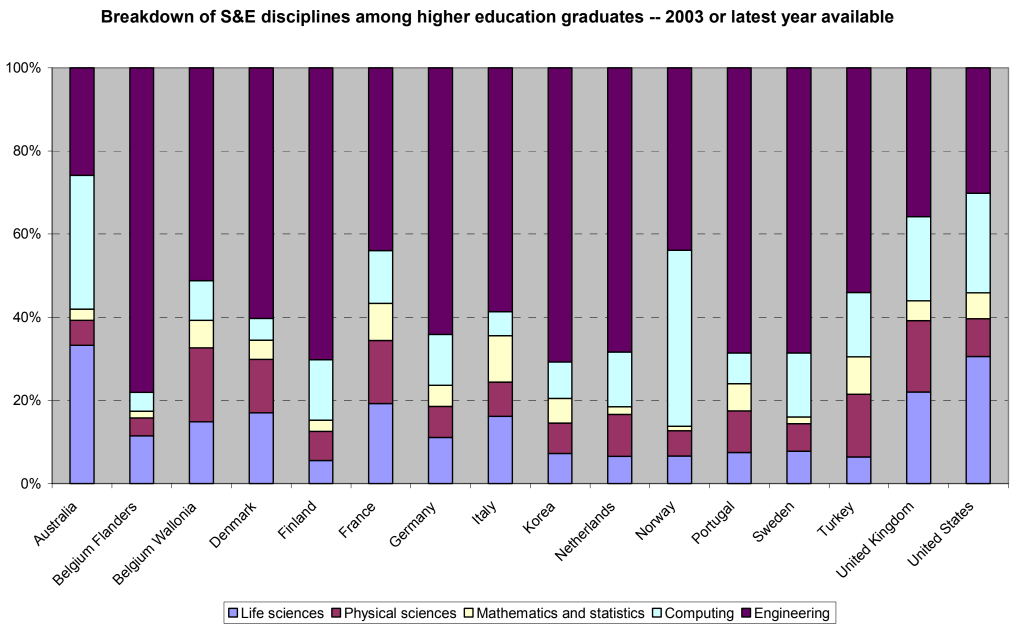


Figure 9.

3.3. A STRONGER DECLINE FOR SPECIFIC DISCIPLINES

3.3.1. In shares

The share of Mathematics and Physical Sciences graduates experienced the strongest decline, while the share of computing graduates increased significantly in most countries.

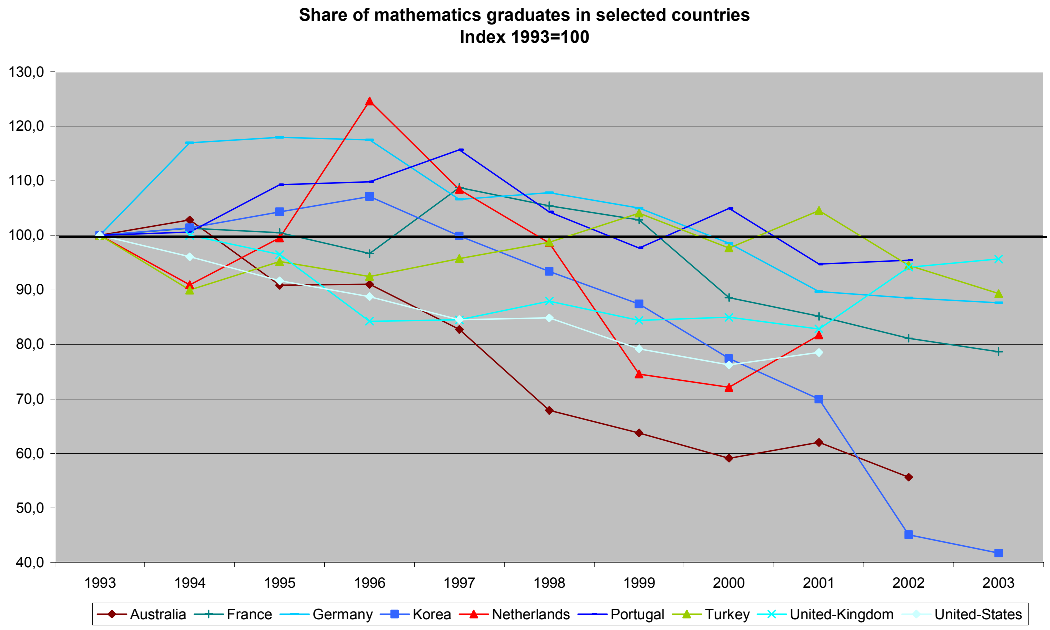


Figure 10.

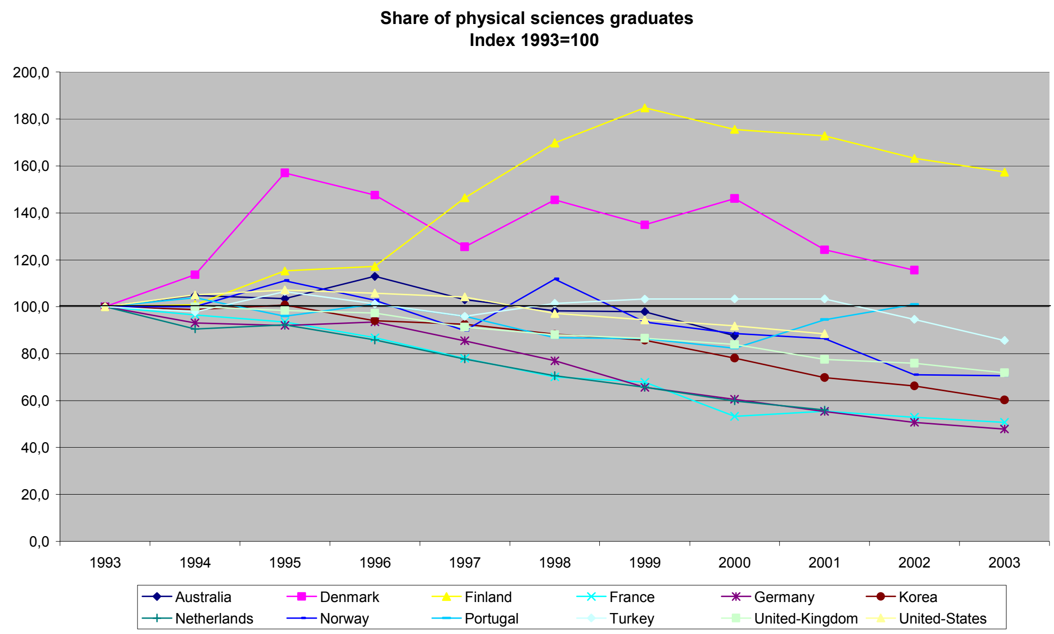


Figure 11.

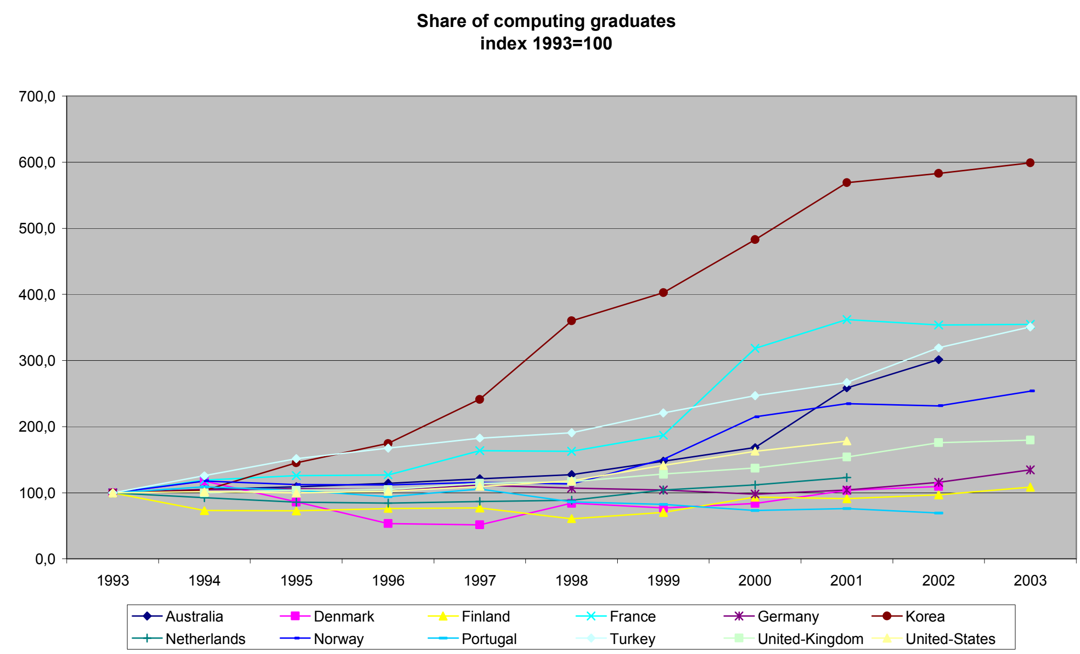


Figure 12.

3.3.2. In absolute numbers

In absolute numbers also, trends are contrasted among disciplines

As figures 13, 14 and 15 show, mathematics and physical/chemical sciences have suffered most while computing studies have been most popular. But the situation here differs more from one country to another and for instance, Portugal, Sweden, Turkey and the United Kingdom have had more positive trends (not shown).

Life science generally had positive trends while engineering presented more contrasted situations (not shown).

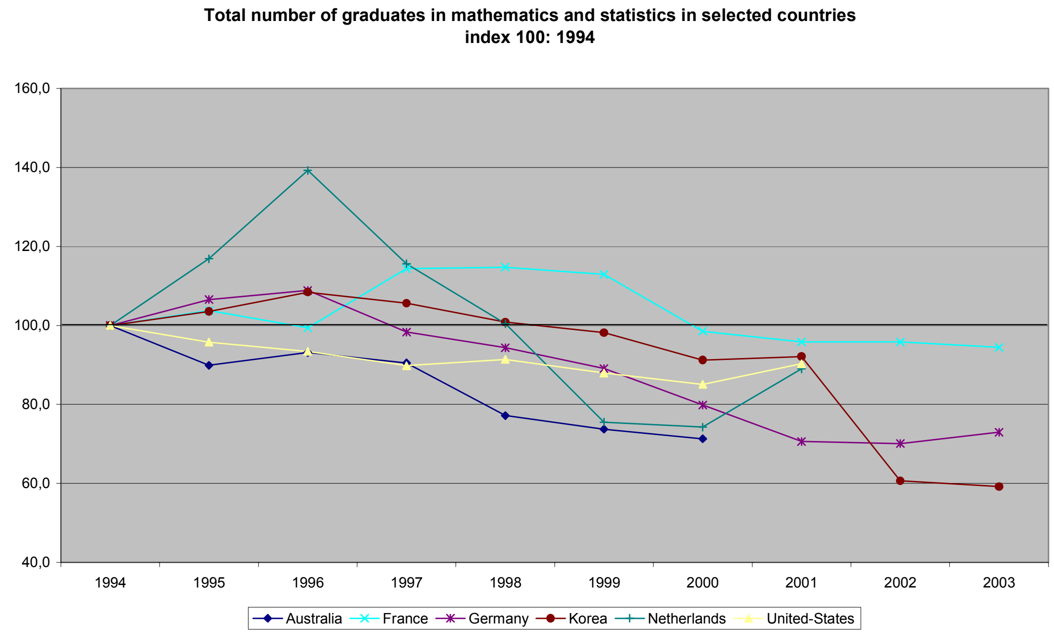


Figure 13.

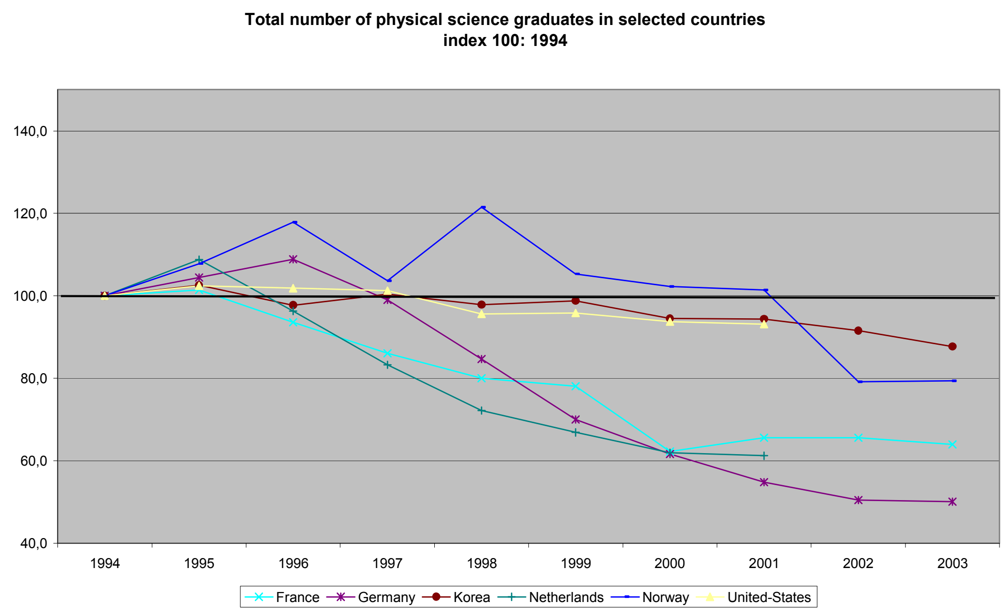


Figure 14.

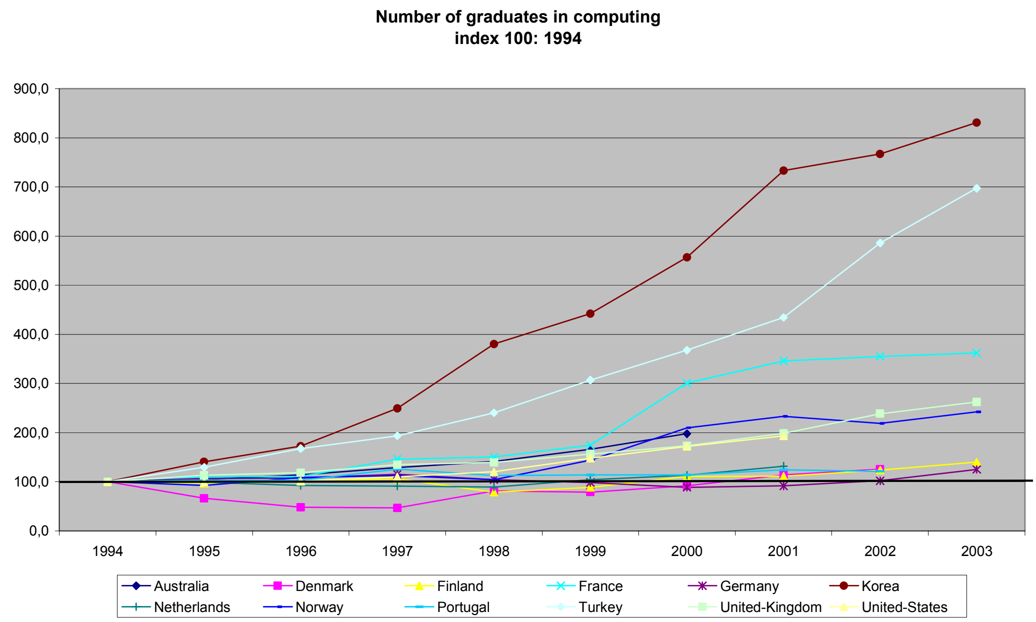


Figure 15.

3.4. A CHANGE IN TRENDS IN THE 90'S

This slow down or decline started in the 90's, at different times for different countries, and is now a general trend for many, as figure 16 shows.

As an example, in France, the number of graduates has declined by 37% since 1995 in physics and 18% in mathematics.

In Germany, they have declined by 50% since 1993 in physics and 33% since 1996 in mathematics.

In the USA the decline has been by 9% in physics and by 11% in mathematics between 1996 and 2001.

Number of graduates in mathematics and physical sciences per ten thousand 20-24 year-olds

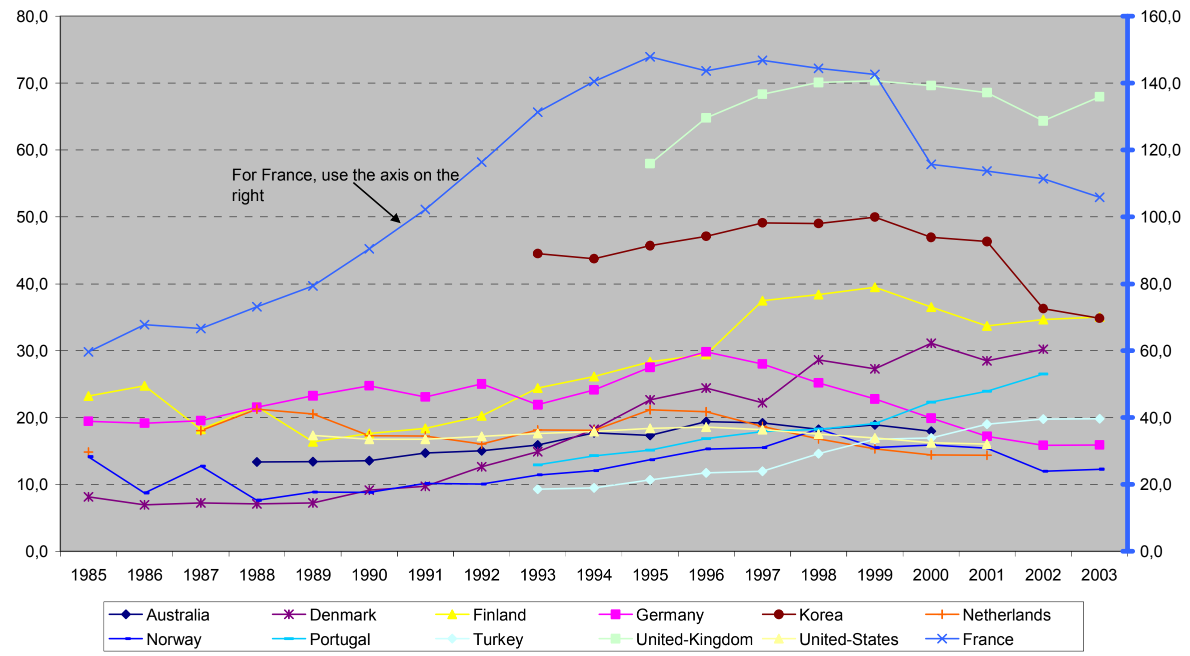


Figure 16.

3.5. A DECLINE IN THE NUMBER OF S&E DOCTORATES IN SOME OF THE LARGER COUNTRIES

The number of S&E 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 17).

Trend in the number of S&E doctorates -- Index 1996=100

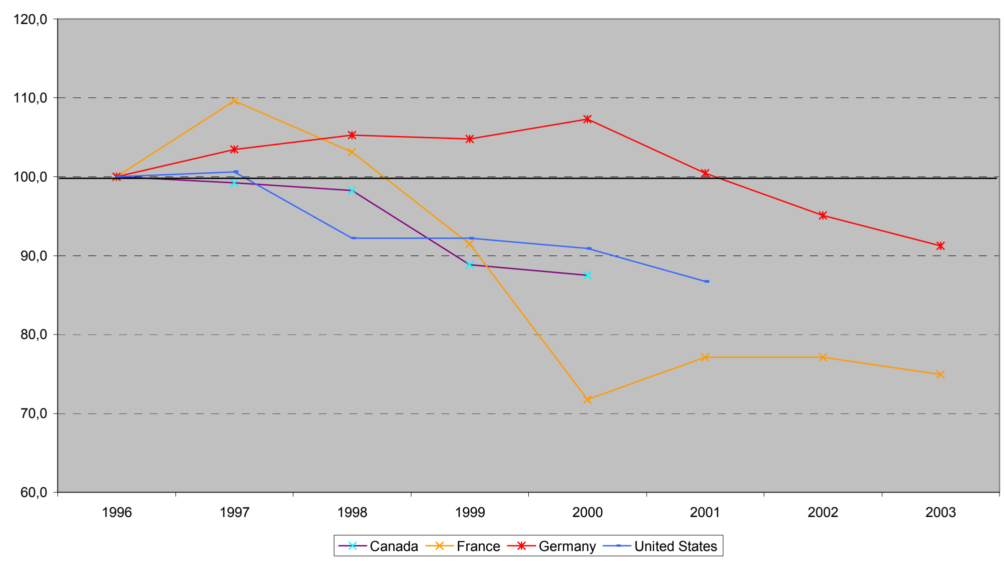


Figure 17.

CONCLUSION:

The strongest signs of decline appear in the proportion of S&E students compared to the total of students, in mathematics, physics and chemistry. This is mostly apparent since the mid-90's. Some countries also show a strong decline in the absolute numbers of S&E doctorates.

3.6. THE NUMBER OF WOMEN IN S&E STUDIES HAS INCREASED MORE RAPIDLY THAN THAT OF MEN

The number of female graduates in S&E has increased strongly over the period in most countries and the increase rate has been stronger than for males in all countries except France and Italy, showing a phenomenon of catching up. It is also important to note that the number of male graduates in S&E has decreased in certain countries (Belgium Wallonia, Germany, Japan, the Netherlands and the United States).

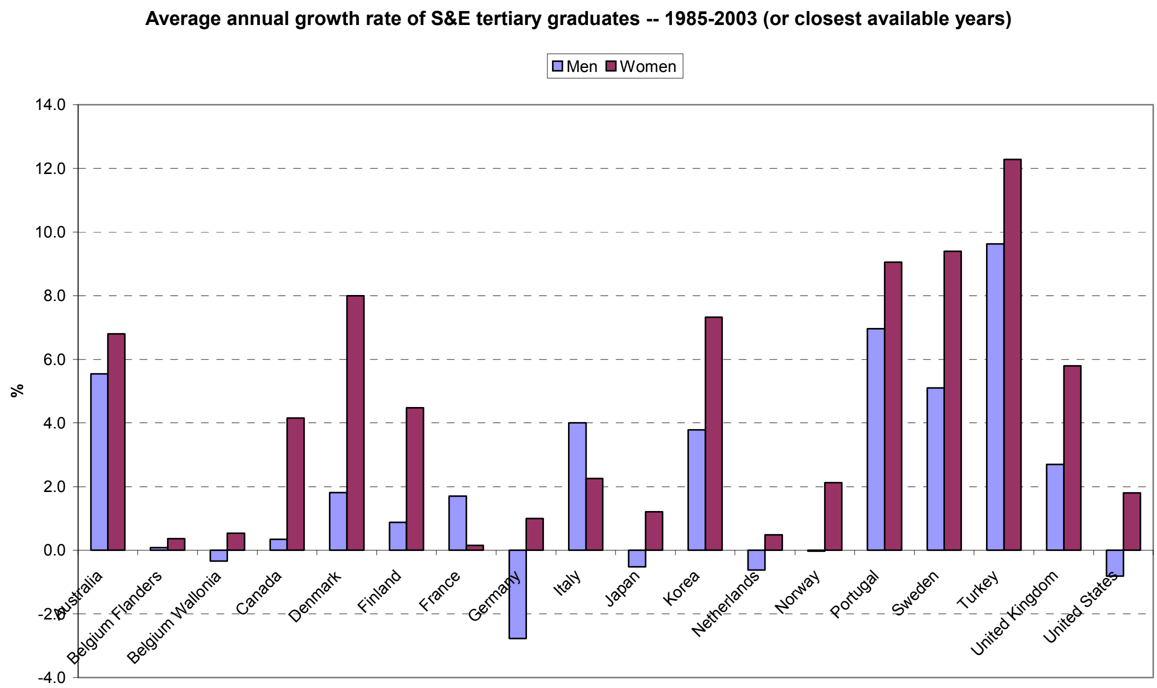


Figure 18.

3.7. BUT THEIR SHARE REMAINS BELOW THAT OF MEN

Still, in most countries, the share of females in S&E disciplines is far below 50%.

The share of women is generally between 20 and 30%, while a few countries show a female proportion over 35% (Portugal, Canada for new entrants and graduates) or under 20% (Japan, the Netherlands). See figure 19.

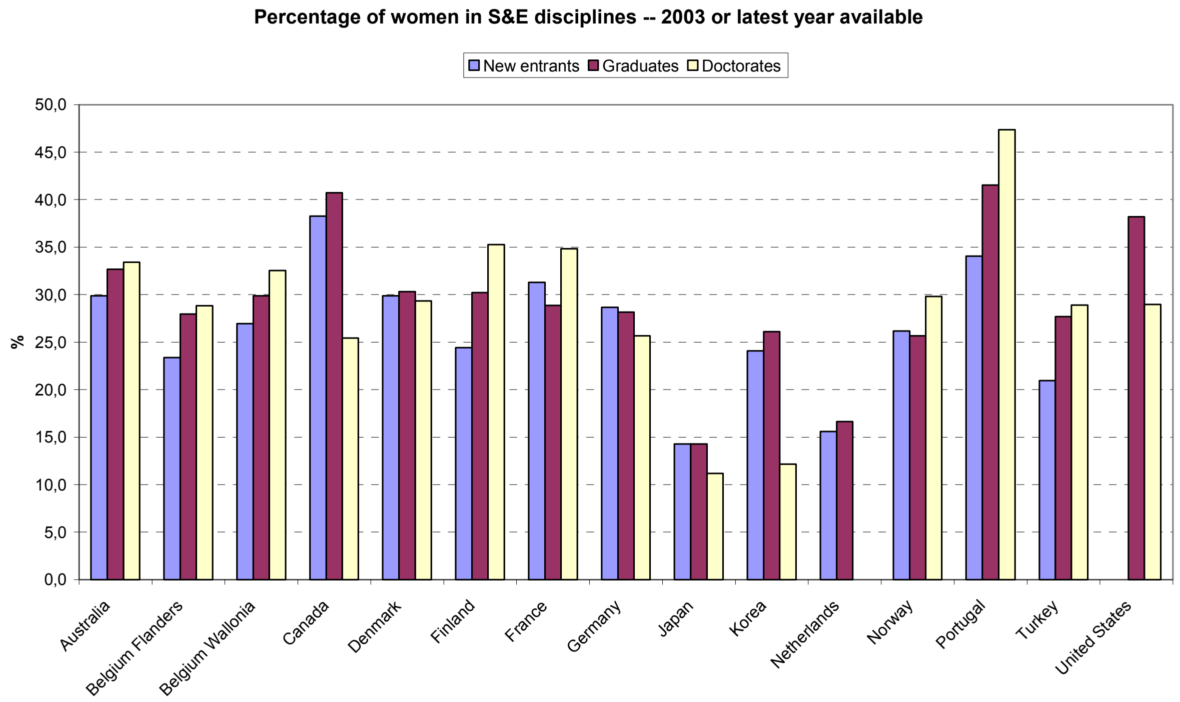


Figure 19.

3.8. IMPORTANT DIFFERENCES ACROSS COUNTRIES AND DISCIPLINES

Women are for all countries more numerous than men in life sciences.

At the opposite side, in most countries, women constitute less than 25% of computing and engineering students. (Figure 20).

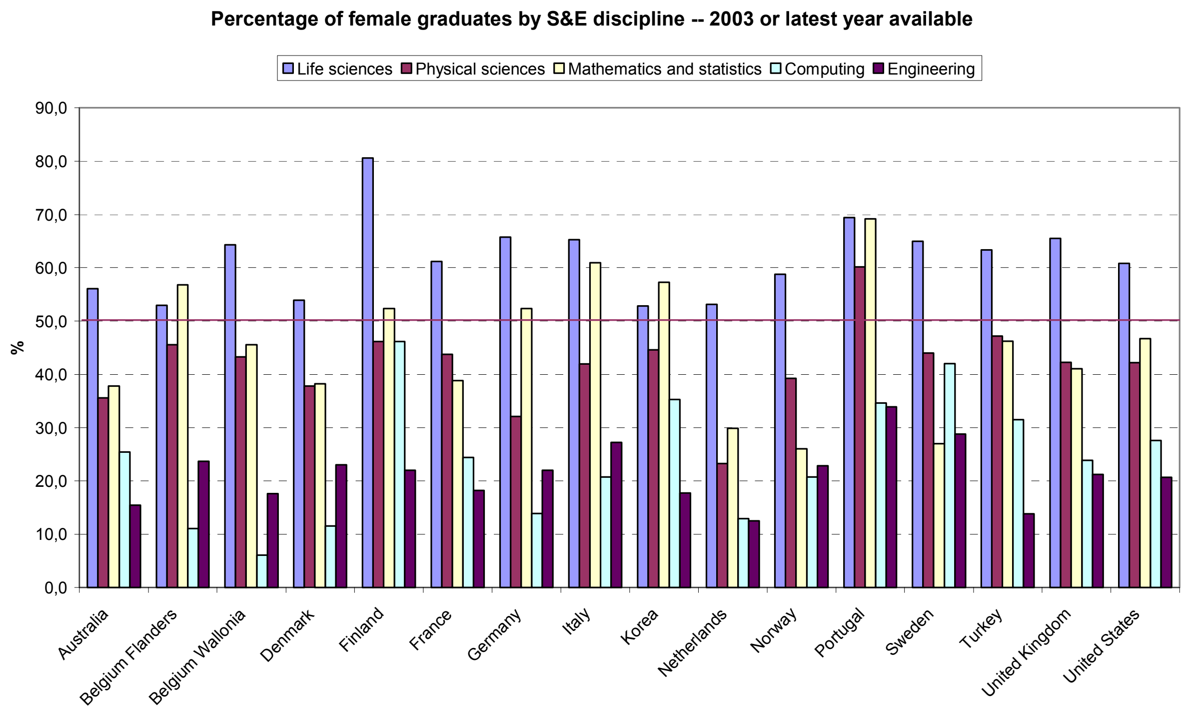


Figure 20.

It is worth mentioning that the **percentage** of female students is quite homogeneous within each discipline over the countries. On the contrary, the **trends** differ strongly within each discipline.

The following series of graphs show the percentages of female students within a discipline (X axis) and its average annual growth rate (Y axis) for new entrants and graduates.

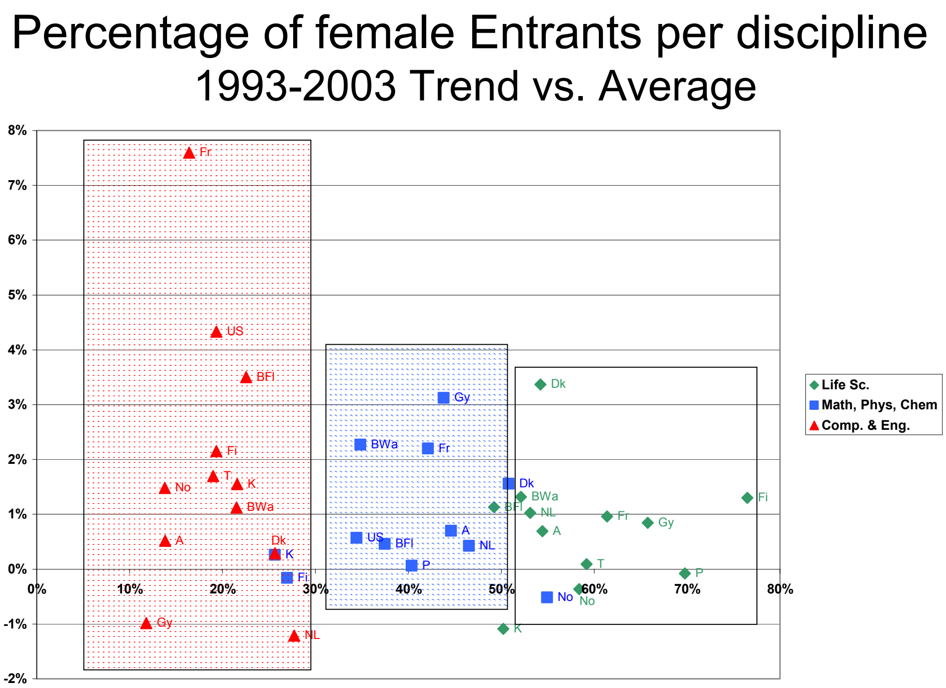


Figure 21. This graph shows on the X axis the percentage of female students and on Y axis the annual trend. This trend is given by the regression line coefficient computed for eaxh discipline in each country.

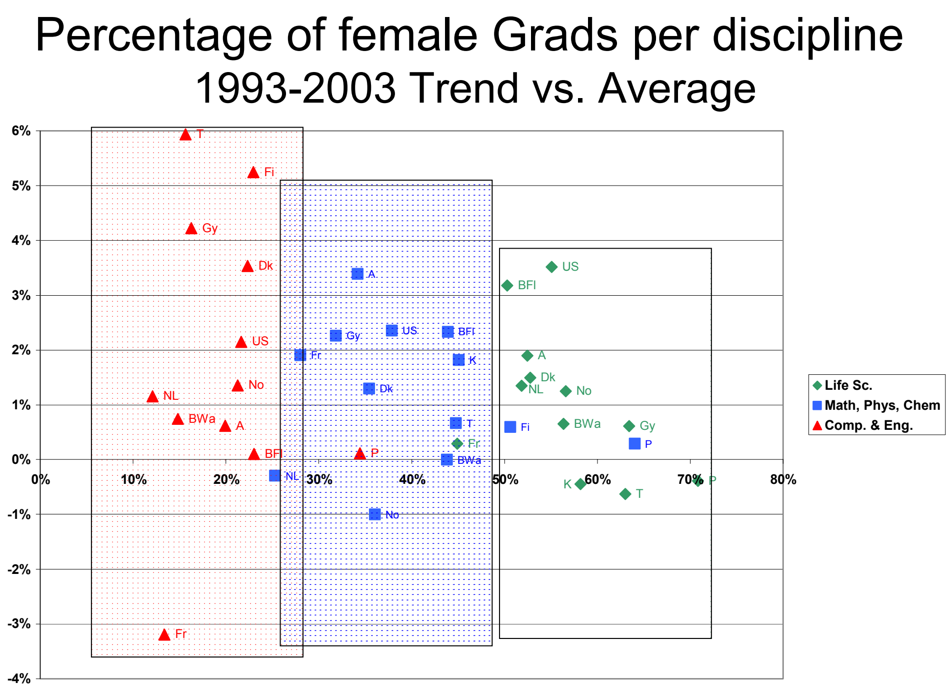


Figure 22. This graph shows on the X axis the percentage of female students and on Y axis the annual trend. This trend is given by the regression line coefficient computed for each discipline in each country.

3.9. A 40% GLASS CEILING?

As figure 24 shows, the female ratio increase rate is generally high in the countries in which the female ratio is low and is lower in countries where the female ratio is high. If we judge by a linear regression of the share of female S&E graduates versus the annual trend (see graph below), it seems that the increase of female student ratio may stop when reaching roughly a 40% share. The same result is found for doctorates.

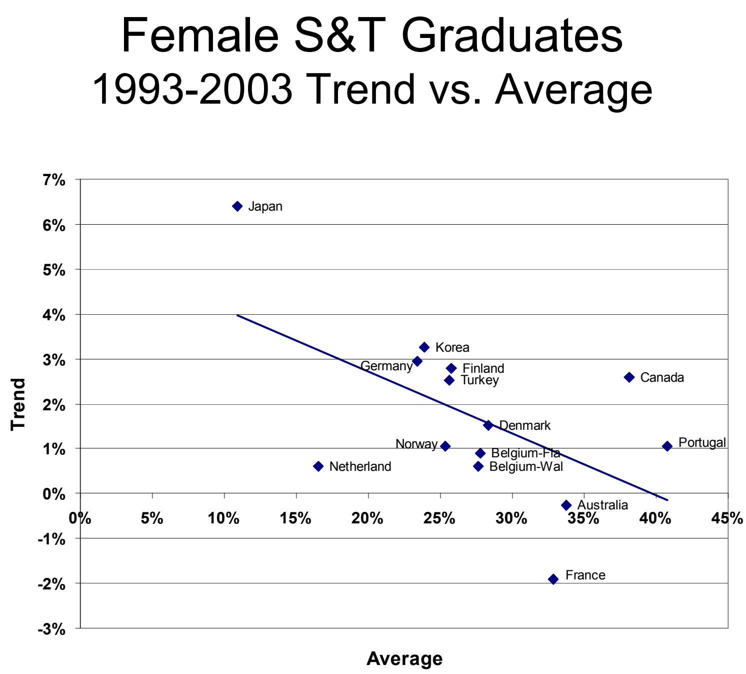


Figure 23.

4. THE SITUATION OF FOREIGNERS

This part could be analysed for only eight countries, due to the lack of data.

"Foreigners" account for the students that do not have the nationality from the country they are studying in.

4.1. EVOLUTION OF ABSOLUTE NUMBERS

In most countries at the graduate level, the number of foreigners in S&E has increased more rapidly than that of nationals and in certain countries (in particular Australia and the United States) their participation in S&E is higher than that of national students

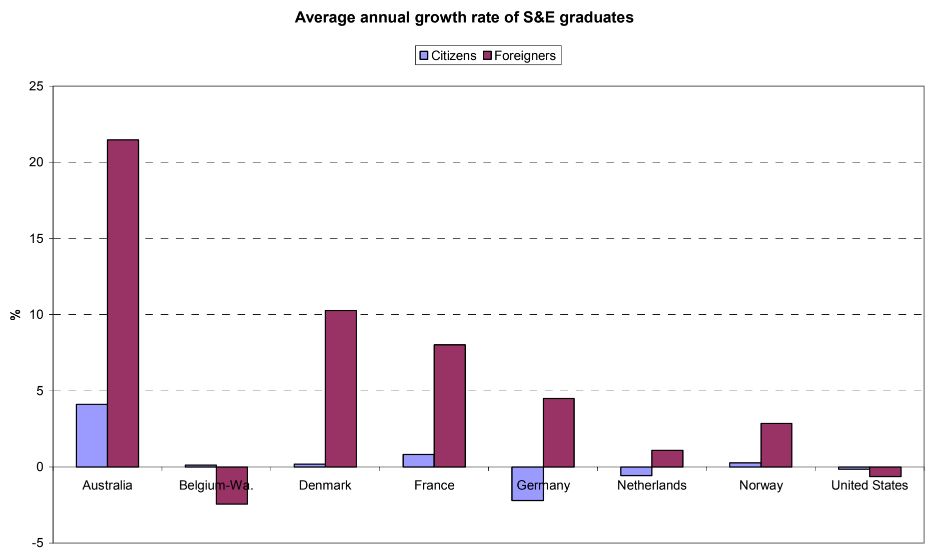


Figure 24.

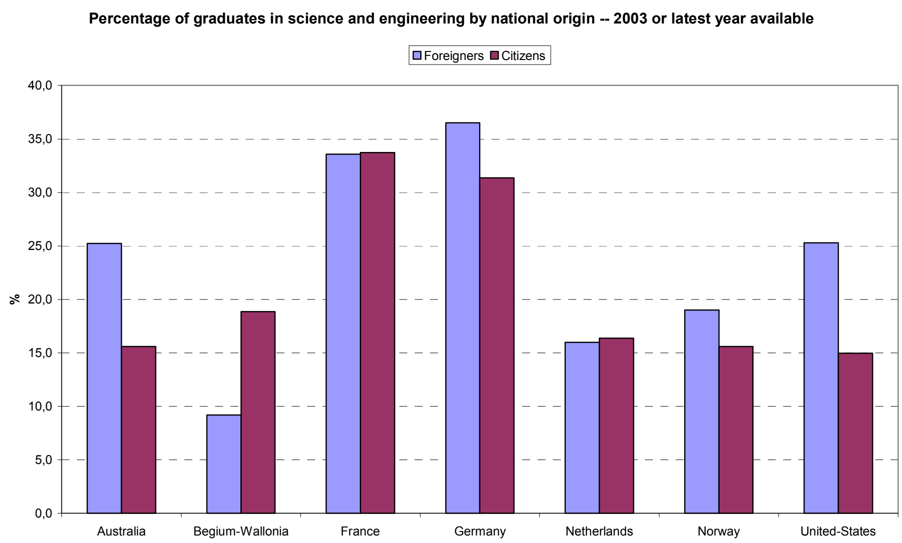


Figure 25.

4.2. EVOLUTION OF THE SHARE OF FOREIGN S&E STUDENTS

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 80's. In Australia, they even represent 27% of the S&E graduates at the end of the covered period (figure 26).

Their share at doctoral level is even larger, with the US having the larger rates (up to 53% in engineering). (See figure 27).

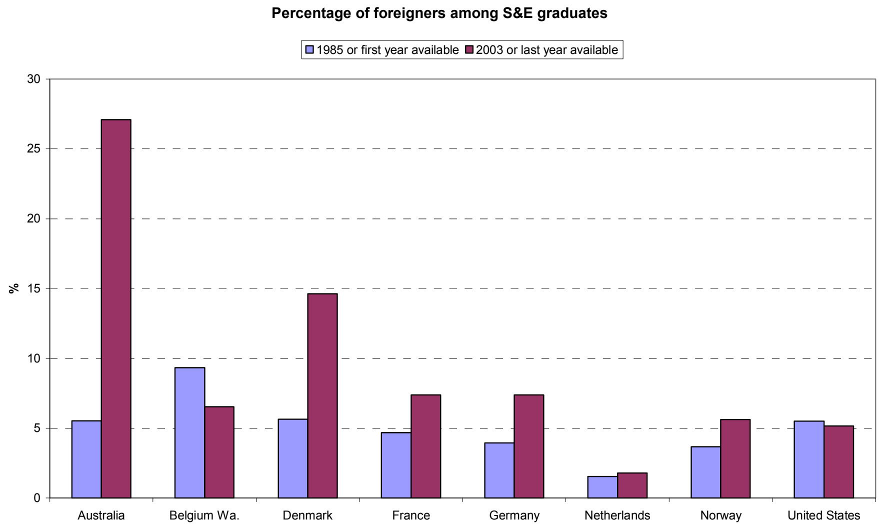


Figure 26.

The percentage of foreign doctorates by disciplines appears to be quite specific to each country with nevertheless higher levels in Mathematics/computing/engineering than in life science and physical sciences.

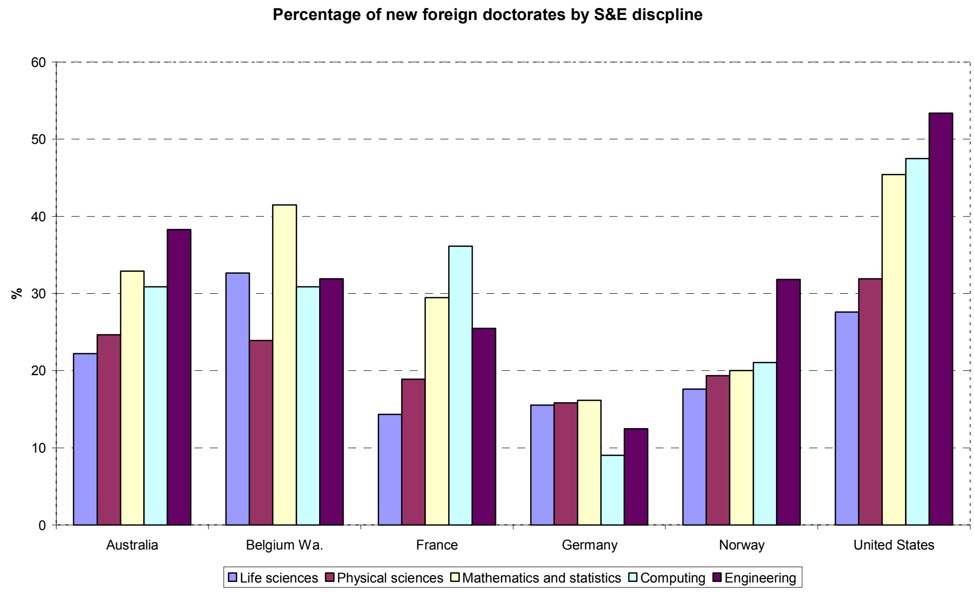


Figure 27.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

There is a decline in S&E studies in relative terms and one in mathematics and physical/chemical sciences in absolute terms.

This decline started around the mid-90's and presents different patterns across countries.

The participation of women has improved over the period but there is a gender specialisation in the choice of disciplines.

The participation of foreign students has also increased over the period and is all the more important at doctoral level.

5.2. RECOMMENDATIONS

5.2.1. Availability of detailed data

Despite the many efforts conducted at the OECD in the field of education statistics, the current statistical system does not provide the breadth of information needed to study the trends in the number of students choosing certain disciplines. The OECD education database currently provides data on the number of graduates by field of education from 1998 to 2003 only. The database would greatly benefit from the following improvements:

- Data on new entrants by field of education
- Data on foreign new entrants and graduates by field of education
- A distinction between graduations and graduates or first-time graduates and/or data on survival/drop out rates by field of education

Besides that, there is a need for better metadata information in order to help the interpretation of the data. Some countries cannot provide data by detailed fields of science and should be encouraged to do so. Lastly but not least, any future revision of ISCED should ensure that it does not introduce new breaks in the time series at the tertiary level.

5.2.2. Data on top students' choice

Our quantitative study presents the decline in the number of student choosing S&E disciplines.

This does not necessarily reflects the actual decline of students interested in S&E studies.

Indeed, as S&E are among valued subjects, a decline in interest towards S&E studies may not directly translate in a decline in enrolment.

Particularly in those education systems where a limited number of positions are available for each subject in higher education institutions[1], there will still be young people to fill in the available positions in S&E.

The decline in interest towards science studies may therefore be more important than the one shown by the data.

For this reason, a useful extension of our study would be to analyze the evolution of the number of candidates for each study position and/or the academic level of those selected (measured through psychotechnics or national exams for instance).

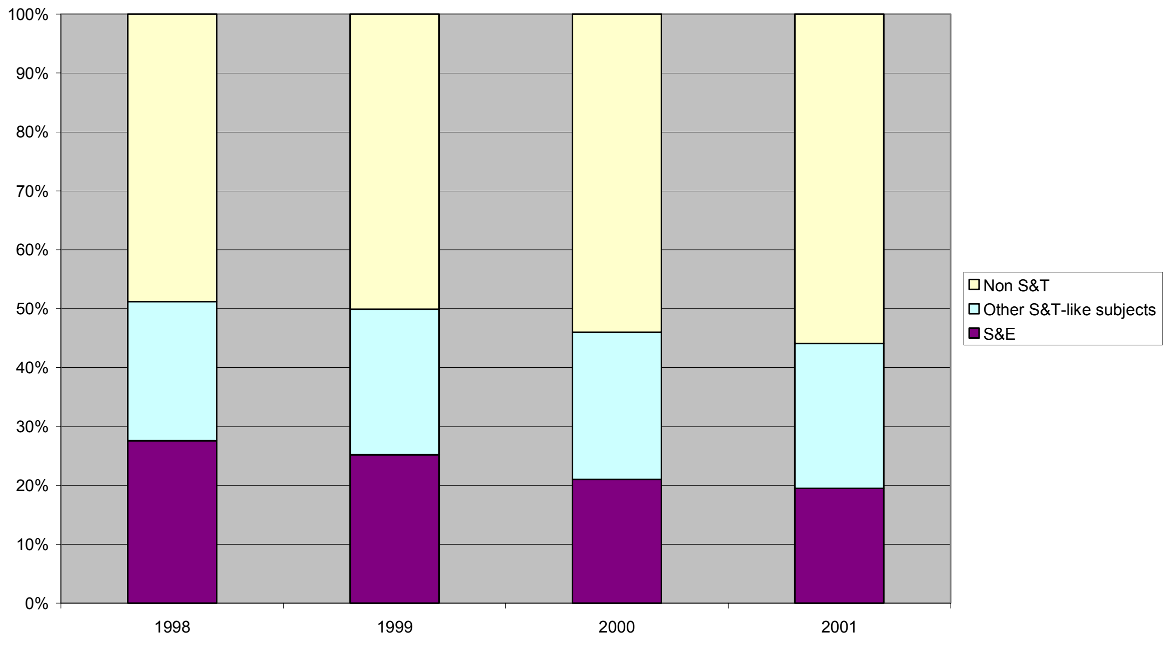
Moreover, in many countries within our scope, S&E were traditionally often chosen by the best students. Many university teachers and other stakeholders say they see a change in this trend and that best students choose less and less S&E. Additional data would be needed on the latest trends regarding best students' choice. The box below shows an example of such analysis in the case of Korea.

Best students' choice in Korea: Source: The Avoidance of Science and Engineering Fields of High School Students in Attending Colleges and Universities in Korea. (Mi-Sug Jin et. al., KRIVET, 2002)

Main points:

The portion of students who ranked at the top 4% of CSAT (College Scholastic Aptitude Test) and who chose S&T-like subjects decreased rapidly from 51.2% to 44.1% in the period of 1998~2001.

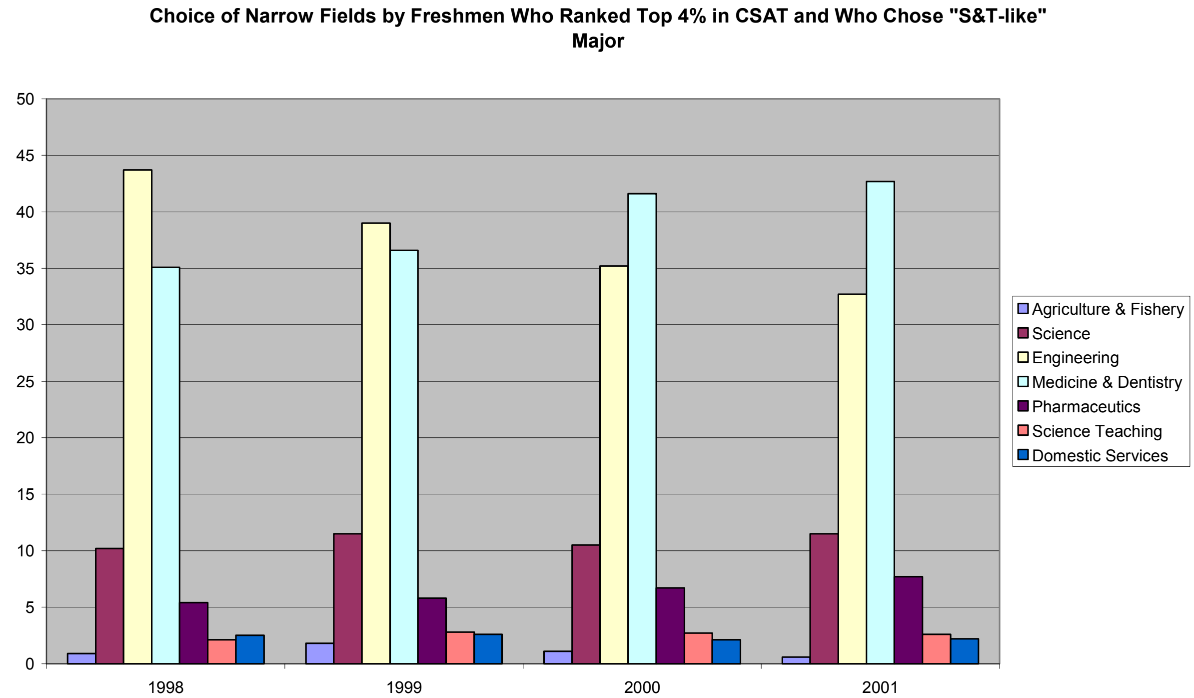
Choice of College Major by Freshmen Who Ranked Top 4% in CSAT



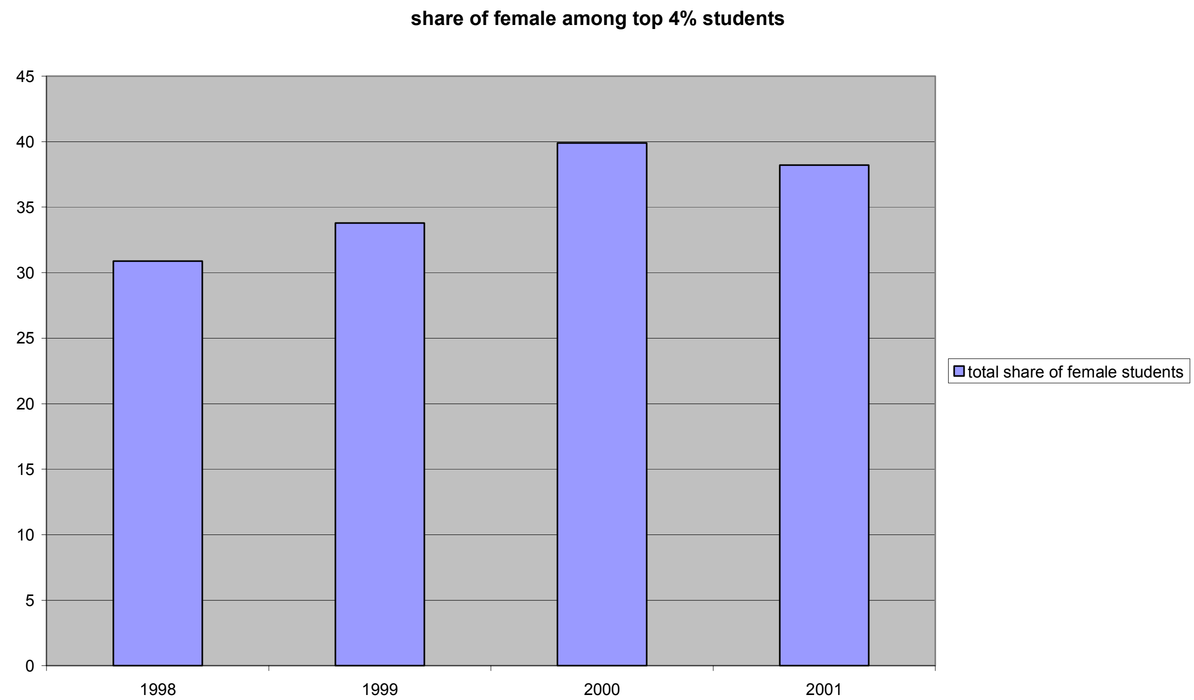
Among those excellent students who choose S&T-like subjects, the ratio of those choosing science and engineering as their major decreased rapidly from 53.9% to 44.2%. This shift occurred in favour of medicine, dentistry and pharmaceutics, subjects that lead to high income professions.

The decrease in choice of S&T-like subjects area coupled with the increasing preference for medical school lowered rapidly the ratio in the choice of S&E by the young bright students.

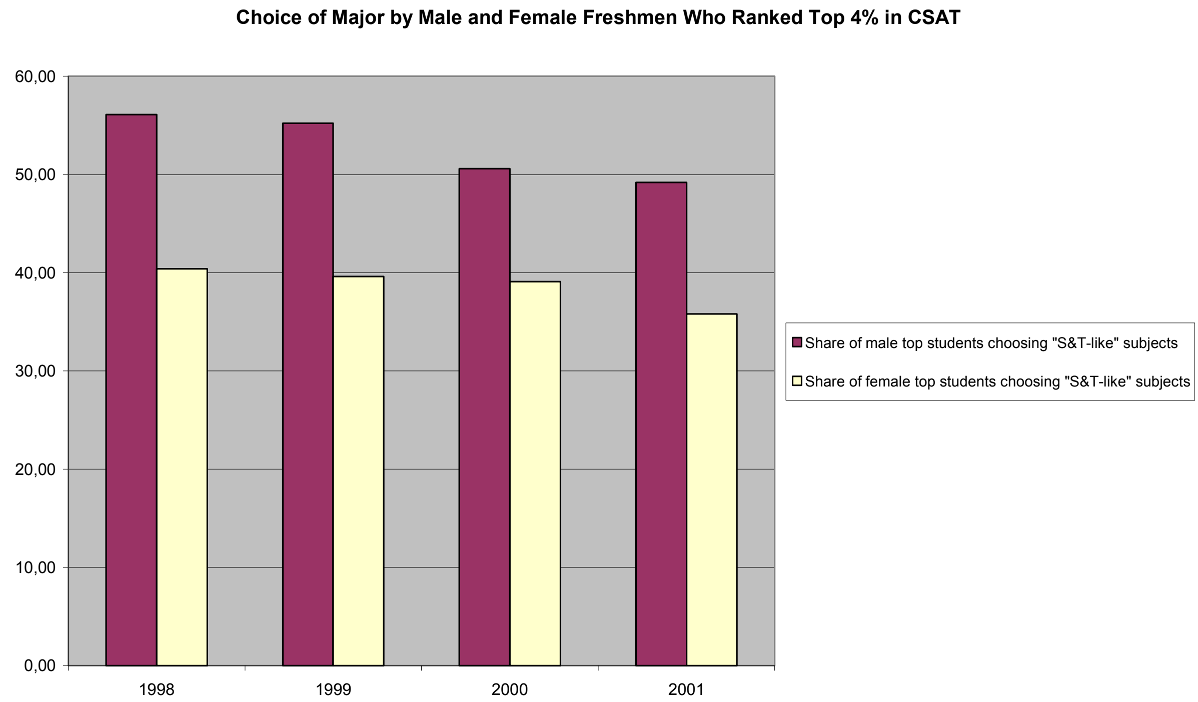
[1] This limitation may be as well the result of a state/region policy as it can be the result of technical availability in existing institutions



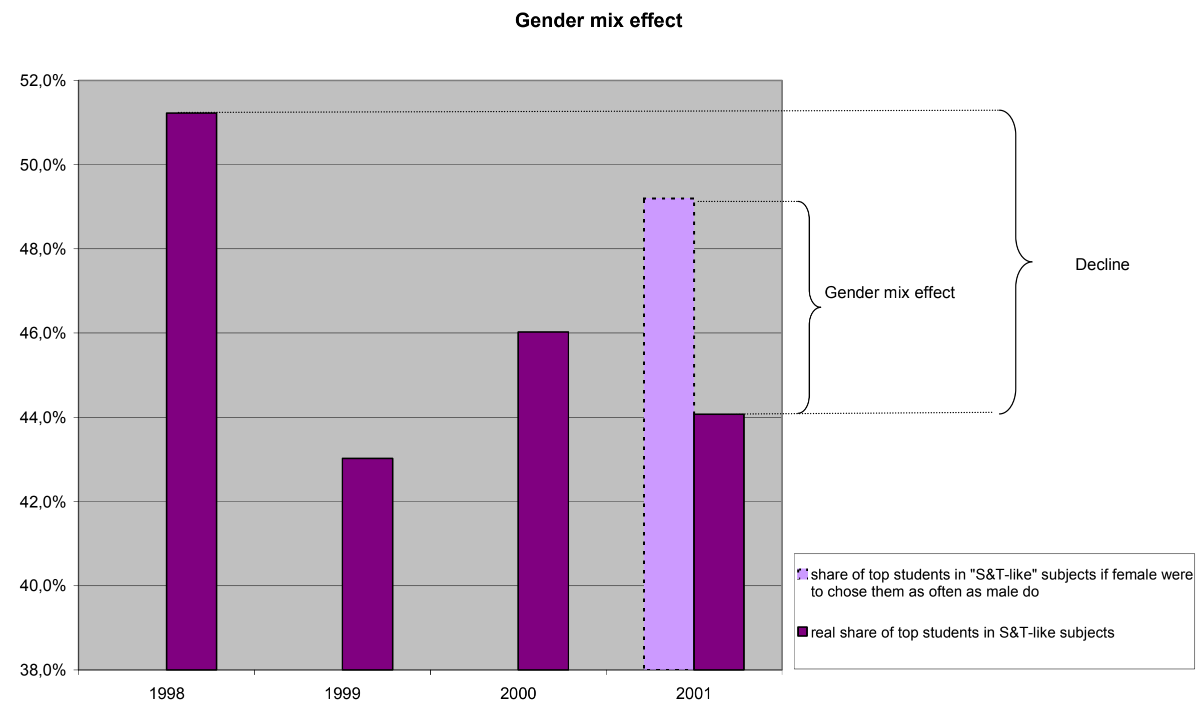
Among the top 4% of CSAT, the female ratio increased very fast from 30.9% in 1998 to 38.2% in 2001. Main reasons for that may be : 1) as the society gets modernized, the equality between sex is emphasized, 2) as the family size gets smaller, number of sons and daughters ranges 1 or 2. Family of modern Korea has one son and one daughter, or one son, or just one daughter. It makes the parents invest their effort and money to their daughters just like to sons.



Traditionally female students are thought to disfavour math and science studies, compared to male. In Korea, females who chose S&T-like subjects were 40.4~35.8% during the period of 1998~2001, while males were 56.1~49.2% in the same period. These numbers show that 1) the gap between male and female propensity persisted, 2) both male and female alike prefer humanities and social sciences to S&T-like subjects more and more.



The fast increase of female ratio among top students coupled with the dislike of S&T-like subjects by females has accelerated the decline in the choice these subjects among top students. Therefore, it may be paradoxically argued that the fast decrease in the choice of S&T-like subjects by top students in Korea was partly caused by the increase of excellent female students



PART THREE: CONTRIBUTING FACTORS

1. METHOD

The factors presented in this part come from the contributions of the working group national experts, completed with a study of science education literature.

This study of literature includes surveys conducted among young people with their own analysis of the reasons why they are attracted to or repelled from S&T studies. More details about these surveys are given in the specific annex. We are careful 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.

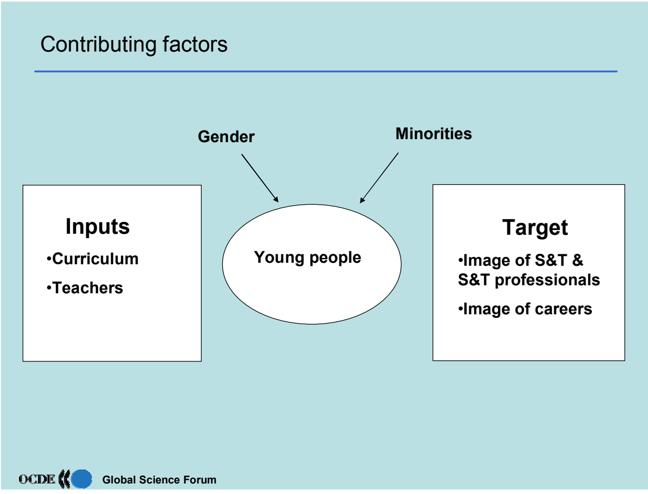
Other sources of information are the numerous research results and some large scale studies (Eurobarometer, TIMSS, PISA…).

We decided to pay particular attention to the earlier stages in the choice process and the building of interest in early youth. This decision, as explained in the methodology section, was based on the fact that interest and taste (which are developed in early youth), are known to be intrinsic motivational factors with strong and persistent impact.

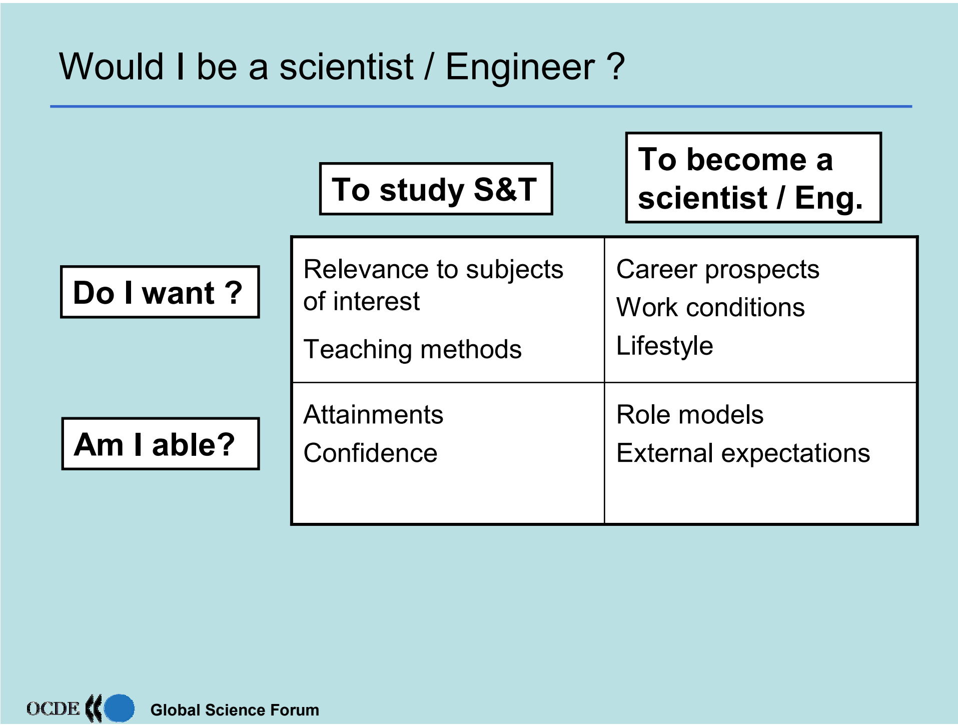
We also decided to pay particular attention to the groups of students that are generally not the main providers of future scientists such as female students, students with average academic records, students from certain minorities and, in some countries, students with less-privileged economic background. We did so because we consider these groups to be important resources in the design of a policy aimed at increasing S&T enrolment.

For better clarity, we decided to group the contributing factors into five categories:

- Image of S&T and S&T professionals
- Image of S&T careers
- S&T education and curricula
- Teachers training, qualification and development
- Gender and minorities



2. SUMMARY OF MAIN FINDINGS FROM THE ANALYSIS



<u>A general context that has evolved since the mid-90s</u>

The factors contributing to a possible decline in interest for S&T studies should be analysed within considerable changes in the general context: economical hardship, evolution of societal values, demographical changes, and a considerable expansion of educational opportunities. It is therefore not surprising that a shift in priorities and choices is being observed among students. On the other hand, science and technology has also permeated many traditional fields of study and professions that now require such knowledge.

The image of science and scientists remains positive but S&T professions are less attractive

Image and motivation surveys show that the perception of science and technology remains largely positive among young people, with some exceptions. In addition, S&T careers are still a choice recommended by parents. However, the perception that young people have of these careers and of scientists' or engineers' lifestyles is not attractive to them. Incomes in S&T careers are often perceived as too low relative to the amount of work and difficulty of the studies required, pupils have a poor knowledge of science-related professions and are largely unaware of the range of career opportunities opened by S&T studies.

Poor opinions towards S&T studies (and dropping out) are often linked to negative pedagogical experience

Children in primary school have a natural curiosity for science and technology, and can form at this stage a long-lasting interest for these issues. However, many primary teachers are not comfortable with science subjects and with hands-on situations, while teaching often focuses on knowledge and facts rather than on understanding.

At lower secondary school level, pupils need to feel the relevance of the subject to their own world. What is taught is often disconnected from cutting edge science or from the recent applications of S&T and often annihilates the interest acquired at a younger age.

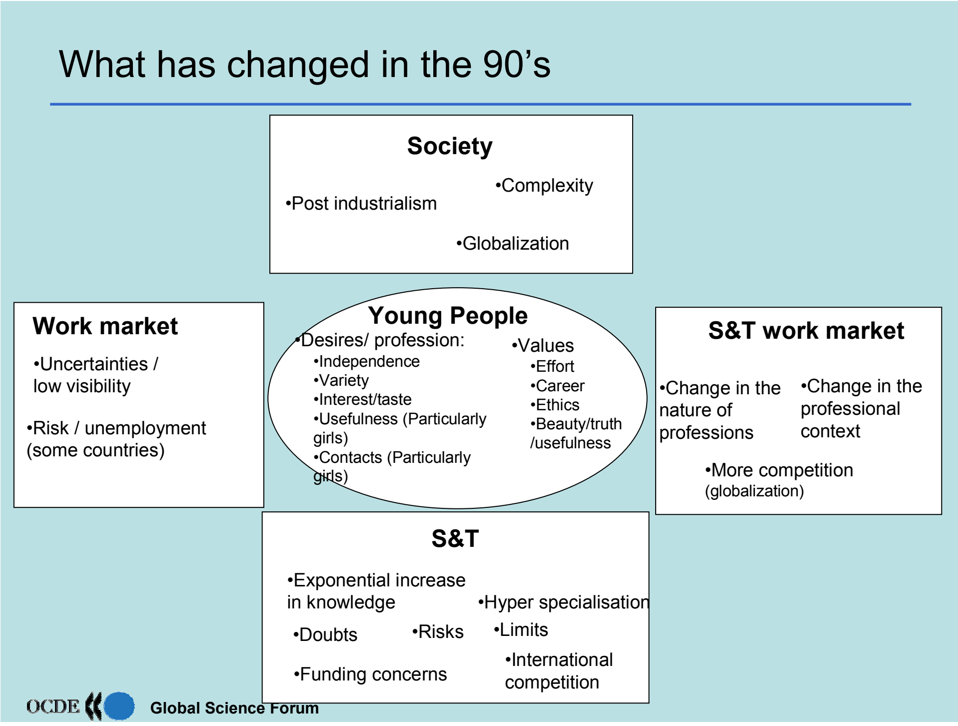
At upper secondary and tertiary levels, S&T topics have to compete with new, trendier, subjects. Tertiary studies and future careers are often based upon their perceived interest ("passion/pleasure factor") by secondary school students.

Moreover, the high drop out rates in S&T in some countries, in addition to mechanically reducing the number of S&T graduates, may deter young people from choosing these subjects.

Female and minority students are not encouraged to follow S&T studies

Female students, and students from various cultural or ethnic minorities, suffer from stereotypes in relation to external (parents, teacher, society…) expectations. They also lack role models (famous scientists, family members etc…) with whom they can identify, and may find themselves isolated in the homogeneous group formed by the majority of the other students studying S&T topics.

3. RECENT EVOLUTION OF THE CONTEXT



Of particular interest are new factors that may have appeared over recent years and influenced the situation since those may not be taken into account in the plans currently being developed in various countries.

3.1. IN SOCIETY

3.1.1. Globalization and complexification

The globalization process induces a need for broader education to understand a more complex and rapidly changing world.

Also, to understand the globalization process itself, young people may feel the need to have a better knowledge of economics and politics and this may attract them towards these subjects.

3.1.2. Expansion of tertiary education and diversification of possible studies

In many countries, the 90's have seen a strong increase in the part of the population acceding to tertiary education

The relative decline (i.e. the decline of the part 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**).

Indeed, the continuous and significant increase of the number of tertiary education students has come along with a modification of the composition of the student's background[2]. New students come more and more often from less privileged social and economical backgrounds[3]. New students have more and more often average academic records (compared with top ones). New students are more often women. New students come more often from minority communities.

And yet, many studies show that these kinds of students traditionally have a lower tendency to choose S&T subjects than the "white male, upper-class, high-academic" student.[4]

One of the results of this dramatic 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 and which may benefit from the young people attraction for novelty may have had strong influence on students' choice in recent years.

3.1.3. Fluctuations in the job market

- Unstable and unpredictable (in 1994 "over the coming period, most jobs will undergo important transformations, as indeed will the way work is organized"; OECD societies in transition, 1994)
- Seen as risky: unemployment = 8% of workforce (average OECD in 1994) (35 million persons)

As a consequence, young people may be prone to operate a shift towards profession-oriented studies..

3.1.4. A change in values?

Post industrialism: less materialistic young people, oriented towards other needs

Much has been written about a hedonistic trend among young people. Some of them seem to prioritise personal fulfilment and private life over work. These persons would no more accept heavy work and its derived sacrifices, and science studies and careers start with a difficult and dry investment period.[5] Some countries, such as Japan, also report a growing emphasis on spiritual values among the general public. [6]

Another trend is about prioritising career and money. People in this category will orientate towards business and economics, law or medical studies as science is not perceived as rewarding enough[7]

Both these trends could be analysed as reactions to the economical crisis and doubts about the future[8]

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[2] **Alalouf 2004 « women and scientific professions »** : the increase of tertiary education students was mainly nourished by female and less-privileged students

[3] **Marc Romainville 1999**, p53 (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")

[4] 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).

[5] **Zwick et Renn (2000**, p101-102), quoted in « Les maths et les sciences n'ont-elles plus la cote ? »; CSRE 2003, p89

[6] **Annual Report on the Promotion of Science and Technology, FY 2003 p26-27 – 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%; reponse to the question "How do you feel about the opinion that future development of science and technology should concentrate on realizing not only material affluence but also on enriching the lives of people": 58.9 I think so; 21.6: I somewhat think so.

[7] **Rand** « In the Netherlands and Italy freshmen clearly prefer law, economic and social and health sciences »

3.1.5. Immigration/minorities

In many countries within the scope of our study, a significant and continuously increasing part of the population was born from immigrant parents or are immigrant themselves. Due to economical, 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.

3.1.6. Social structuring

The importance of fathers in the development of attitudes towards S&T and the construction of interest and motivation is well established. As the number of single-parent (mothers) families[9] increases, the fathers' influence may decline.

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 then, 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[10]

3.2. IN S&T

3.2.1. Image of and interest in S&T

The studies do not show any definite decline in people interest in S&T. The decline seems to be confined to S&T studies and careers. But, as the SAS & ROSE studies suggest, the more developed a country is, the weaker its young people's interest towards science is likely to be. (Perhaps, since S&T progress is taken for granted in such countries, new challenges are about developing other fields such as leisure and service). Also, some people find that the pace of science is too fast. Then, they wonder why they should want to work on making it go faster[11]

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[8] **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 emphasized. 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. "

[9] According to Zwick et Renn (2000, p101-102), quoted in « Les maths et les sciences n'ont-elles plus la cote ? »; CSRE 2003, p89

[10] **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"

[11] **EKOS** e.g. 64% of Canadians agree that technologies are developing faster than our capacity to deal with the ethical issues associated with them

3.2.2. Pace of information

The knowledge young people have about science comes mostly from the media.

As a consequence of the pace of information in the media, scientific discoveries are expected to emerge with a very rapid pace. Some sciences succeed in feeding the media continuously with novelty: mostly computing sciences, biology and health. Some others, as physics or chemistry, do not.

3.2.3. Funding difficulties

In some countries, the media have widely publicized about the S&T community's dissatisfaction with recurrent funding difficulties.[12] The international media coverage of these difficulties has been quite extensive and over a long period. On example was the French action "let's save research" with demonstrations and strikes in 2005.

3.2.4. S&T work market

Is there a change in the nature of the profession? During these last decades, very large projects have emerged, with enlarged team work and managerial functions. S&T professions now involve a need for more and more professional skills such as communication and teamwork.

In some countries, the public/private funding proportion changed towards more private funding or was in the process of changing in this way.

Due to media coverage, the S&T work market may have been perceived as subject to strong international competition. (brain drain/brain gain)

3.2.5. Negative developments

Sciences and Technologies are seen in a less univocal way than they use to be: they are the driving force for progress but also increasingly generate concerns about the fact they may be going too rapidly (e.g. GMO), too far (e.g.. cloning) or generating risks we will not be able to manage (e.g. global warming).

- too far?

This last decade has been marked by numerous societal debates on "what limit put to the S&T developments?"(assisted reproduction, cloning…)

- Too rapidly?

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[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.

Due to the acceleration of process as much as for economical and political reasons, the technological devices come to development and production phases far more rapidly than it used to be, inducing growing concern about safety among public opinion (GMO's, new pharmaceutical products…)

- Not able to handle its side effects?

Some of the strongest fears & concerns among the general public are about the side effects of S&T: global warming, endangering of the ecosystem, mad cow disease…) (see for instance Eurobarometer).

4. IMAGE OF S&T AND S&T PROFESSIONALS

In this part, we first explore the **general perception young people have of S&T and S&T professionals** "as a whole". Is this world attractive to them? Is it familiar to them? How do they see it? What value do they give to S&T as to their utility for society and for themselves?

The second question analyzed here is "what is **their actual knowledge of this world**?" Are they able to say precisely what is inside and is outside S&T?

When information about general population perception of science was available, we found it useful to present it also as it is certainly influential on young people too and on prescribers as part of the general society (parents, teachers, career counselors…)

The result of our work shows that young people have a rather positive but quite imprecise image of S&T world.

<u>**Main findings:**</u>

Positive points:

- In most countries, polls show a rather positive image of science among the public.
- S&T are considered important for society and its evolution.
- Scientists are among the professionals that the public trust most. [113],[14]

Neutral or double-sided findings:

- The general public does not feel familiar with the worlds in which science and scientists evolve.
- S&T are often considered as unattractive subjects

Negative points:

- Some concerns are recurrent on specific points like in reproductive biology or genetically modified organisms but do not seem to influence the perception of science as a whole.
- Young people seem to have a very vague idea of what S&T professions are

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[13] **EKOS**: 77% of Canadians would recommend a career in science to their own child or young relative

[14] **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)

4.1. S&T AND S&T PROFESSIONALS STATUS

4.1.1. Prestige & utility

- **Findings**

- **Prestige**

S&T:

In most countries, polls show that science is considered important. The public seems to believe that science will provide responses to current issues and will improve the quality of life.

Nevertheless, the image of science is not unambiguous (GMO'S, global warming…)

S&T professionals

S&T professionals used to be among the most prestigious professionals at a time where they were among the few educated people. Many elements show that this prestige has declined.

As an example, it can be argued that in many countries, most higher management positions are taken by non-scientists, even in technology intensive companies and in government (for instance in Korea & Germany).

Also, very few high-level scientists are recognized by name, whereas CEOs and sportspersons are. Very often, when the media cover a science event, the scientists behind are not the focus.

On the other hand, if the social position of scientists has weakened, it is still among the professions that parents may recommend to their children.

One type of S&T professionals that most young people know is S&T teachers. Thus they have generally a significant impact on the image young people have of the S&T profession as a whole.

And yet, S&T teaching is not generally a highly respected or valued profession.[15]

- **Utility**

Scientists and engineers are no longer symbols of social progress. They compete with other occupations (economics, social services, medicine, media and marketing) regarding their social utility.

As was shown in SAS study, it appears that the social utility accredited to scientists tends to decline as

[15] **Talking about leaving** - Seymour, E. & Hewitt, N. - USA - 1997 : "teaching was consistently portrayed as an "alternative or "deviant" career, which a handful of switchers and non-switchers pursued despite the disapproval of faculty, family and peers". "We commonly heard that more people would follow their inclination to teach were the pay or prestige of the profession better, or were it less time-consuming and expensive to undertake an education qualification on top of a baccalaureate degree." "students also saw teaching as a form of professional activity that was undervalued by the wider community. It seemed to pay poorly compared with other options, and family and peers tried to dissuade them from choosing to teach" "There was no doubt in the minds of that fifth of our overall sample who had considered teaching as a career that their ambition was regarded as deviant by most of the significant people in their lives"

[16] **SAS** results ("pupils' experiences and interests relating to science and technology" Sjoberg): "A significant part of the children in the rich countries, often express sceptical and negative attitudes and perceptions in their responses to several of

the development level of countries increases. Thus, in developing countries, scientists are still considered with much respect whereas in most developed countries there are just professionals among others. [16]

Younger generations have less positive perception towards the social utility of S&T than older generations do. In a public opinion survey in 2004 (Japan), 58% of 18-19 yrs agreed 'New problems in society will be solved by S&T', while 64% of 20-29 yrs, 69% of 30-39 yrs, over 70% of 40-69 yrs agreed.

However, school children recognize science as important for the development of a nation. About two thirds of students at every grade from 5 to 9 responded affirmatively to the question 'Science is very important for the development of a nation', in a national survey in 2004 (NIER, 2005).

- **Supportive elements**

Finnish Science Barometer 2001 & 2004:

-Although science per se is highly respected and scientists as a occupation group have a high respect, They have poor name recognition.

- The general image of science in Finland is unambiguously positive. Expectations concerning the import of scientific research are optimistic, but not excessively hopeful

Eurobarometer: Europeans Science & Technology, 2001:

- Overall positive perception of science and technology (despite recent crises and the fact that science is also perceived as a kind of Pandora's box)
- Europeans have high expectations about science and technology but...
- Science and technology are no longer considered a panacea for a series of problems
- Interest in science slightly lower, in relative terms, than in 1992 (sport scored higher than science)
- The perception of science is no better or worse among young people than among the public as a whole
- Only 30% of respondents feel that the disaffection for science studies could stem from a poor image of science in society.

EKOS: This study on Canadian perception of science shows that a very large majority of respondents have a positive view of science. [17] But they consider scientific theories change too often for them to keep informed. [18]

"Choosing science at 16" (Munro & Elsom , 2000):: Surveyed teachers believe that the way science is portrayed in the media play a significant and negative role in student choice[19]

Osborne "Attitudes towards science" (UK):

- Young people know very few contemporary famous scientists [20]

the SAS items. (…) Many of the data indicate that science and (even more?) Technology has a problem with its public image in many developed countries."

[17] **EKOS**: A majority of Canadians agree that science will solve issues like disease and pollution (79%), provide Canada the ability to maintain a self sufficient food supply (77%) and agree that science is helping use of natural resources in a more sustainable way (73%). (…) Nine in ten Canadians have a favourable impression of both science and research and over four in ten have "very favourable" impressions of both.

[18] **EKOS** 36% of Canadians 16 to 23 years of age agree that scientific theories change so often they do not know what to believe anymore

[19] **Choosing science at 16** "the media were mentioned often by teachers, particularly regarding the general unfavourable way they portrayed scientists and engineers and their life-styles in relation to those of more glamorous groups"

[20]**"Attitudes towards science":** "Perhaps most fascinating was that, if asked to name famous scientists, the overwhelming majority of students identified Einstein, Newton and Bell, demonstrating a total lack of any *contemporary* role models."

- Secondary education students see science as important in everyday life (87%), but only 68% see it as useful and 58% as interesting.[21]

***Public Opinion Survey,* Cabinet Office, Government of Japan – 2004:** Younger generations have less positive perception towards the social utility of S&T than older generations do[22]

NIER, 2005, Japan: School children recognize science as important for the development of nation.[23]**Technology Day survey (2004) in Flanders**: General public feels that STI are important for society and its evolution (93% agrees) and that it is important that the Flemish government invests in research (same %) and in activities to promote this (91% agrees). However, 59% agree that STI are very boring and not exciting.

Euroscene report for Flanders

SAS study

Public Opinion Survey, Cabinet Office, Government of Japan (2004, in Japanese),

Results of 2004 **National curriculum achievement survey** – elementary and lower-secondary schools, NIER (2005, in Japanese)

Results of **survey on students' motivations toward science learning** – national situation, Ogura (2005, in Japanese)

4.1.2. Financial status

- **Findings**

S&T:

As a field, scientific research is often seen as subject to strong financial restrictions. This could be perceived as a sign that governments consider it as a "not-so-high" priority activity.

S&T professionals

"Scientist" is not expected to be a high income job by young people.

Few students think that learning science relates to becoming wealthy.

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[21] **Osborne, J. Attitudes towards science (UK):** "Similarly, a large-scale market research survey conducted in the UK for the Institute of Electrical Engineers (The Research Business 1994), based on a sample of 1552 students aged 14–16, found that students saw science as useful (68%) and interesting (58%), and that there was no significant distinction between genders. Again a large proportion saw the relevancy of science as a reason for studying it (53%) and that it offered better employment prospects (50%). Moreover, 87% of students rated science and technology as 'important' or 'very important' in everyday life."

[22] **Public Opinion Survey,** Cabinet Office, Government of Japan – 2004: In a public opinion survey in 2004, 58% of 18-19 yrs responded affimatively to question 'New problems in society will be solved by S&T', while 64% of 20-29 yrs, 69% of 30-39 yrs, over 70% of 40-69 yrs did so.

[23]**NIER, 2005, Japan**: About two thirds of students at every grade from 5 to 9 responded affirmatively to question 'Science is very important for the development of nation', in a national survey in 2004.

- **Supportive elements**

Japan - Ogura, 2005 : About 10% of students at grade 5-12 responded affirmatively to question 'Person become more wealthy by learning science.', in a national survey in 2005.

4.2. KNOWLEDGE OF S&T AND S&T PROFESSIONALS

4.2.1. Stereotyped images

The scientist is a white man with a beard and a white coat. (SAS)

Technology: the technician does a dirty and repetitive job

- **Supportive elements:**

Woolnough Changing pupils' attitudes to careers in science. "There is clearly a need for conveying a less stereotypical picture of what scientists do in their work, for many express very simplistic, often quite false views. Comments such as "I want to work with people and scientists don't do that", "I think engineering is a man's job", "I want to be a nurse and so don't need science" suggest that there is still much misunderstanding about what careers in science entail."

"Self-to-prototype matching as a strategy for making academic choices. Why high school students do not like math and science" Hannover B. & kessels U., Learning and Instruction 2004

Talking about leaving - Seymour, E. & Hewitt, N. - USA - 1997 : "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.

4.2.2. Lack of knowledge and misperceptions

Young people do not have a clear idea about what scientists really do. What young people in general know about certain professionals' life comes from knowing someone in the job or by the media. Role models for scientists are lacking or unknown.

The media may play a role in this unfavourable view.

- Young people have few opportunities to know about scientists and their life and they seem to hold low level of interest in what scientists are.

Some studies show that science is considered as unfamiliar to most respondents

- **Supportive elements**

- **National survey in Japan** (Ogura, 2005):
- - 70-80% of students at grade 5-12 answered that they have never had a science lesson in which a scientific expert come to their school and talk about science.

- \- 20-30% of students at grade 7-12 responded affirmatively to question ‘I want to listen to scientists or engineers’.
- \- Students who have had lessons given by a scientific expert tend to respond more affirmatively to the question than students who have not had

“Public Opinion Survey on Science and Technology and Society" in Japan (2004):
the percentage of citizens who replied “I agree” or “I somewhat agree” to the opinion “Scientists and engineers are close to the public and are felt familiar” accounted for about 15%, while the percentage of citizens who replied “I don't agree” or “I somewhat don’t agree” accounted for more than 70%” (p46)

“Towards a clearer understanding of students' ideas about science and technology” (Hill and wheeler 1991):
This study suggested that students do not have a well-rounded appreciation of the nature of science and the work that scientists and technologists undertake. Pharmacists and media technicians, for example, were not considered to be doing scientific work.

“Framing choices: a longitudinal study of occupational aspirations among 13-16 year-olds” (Furlong and Biggart 1999) demonstrated the narrowness of students’ views about science work

Finnish Science Barometer 2001 & 2004: A quite good and visible image of the scientists´ life and working conditions at the Academia

“Outlook on scientific and technical professions” (CCSTI Grenoble): young people have a more precise knowledge of science application than of scientific professions.

“Choosing science at 16” (Munro & Elsom , 2000):
“the media were mentioned often by teachers, particularly regarding the general unfavourable way they portrayed scientists and engineers and their life-styles in relation to those of more glamorous groups”

5. IMAGE OF S&T CAREERS

The career choice is the joint answer to two questions: Can I see myself as ____? & What can I do with____? (What can I be? What can I do?)

This study is not aimed at analysing the economical efficiency of the choice of a S&T career against the other possible choices. The objective of this part is rather to outline the perception that young people have of S&T careers, as a factor that may significantly contribute to the decline of their choice of S&T studies. Nevertheless, when relevant, and when such data are available, we will try to make the link between the young people's perception of S&T careers and the actual situation.

There is not one single unified work market for S&T workers. The situation differs significantly in four kinds of organizations: Industry/Business, University (research & teaching), secondary education institutions (teaching) and publicly-funded research organizations. However, young people may have a limited perception of these differences.

We chose not to focus only on top S&T careers but to explore the whole spectrum of S&T careers.

Moreover, the choice of S&T studies is not always directed towards S&T careers as many non-S&T professions require some S&T background (ex: Architect). For this reason we chose to include such careers in the scope of our analysis (Science as a tool for non-science careers).

5.1. WHAT YOUNG PEOPLE SAY ABOUT THE REASONS FOR THEIR CAREER CHOICE

What adults say about it:

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?", asked 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 the actual scientists say about it:

Nearly all the scientists asked in the Bayer Facts study[24] (91% female and 95% 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 about it:

The main criterions for choice of a profession are (see supportive elements under):

1/ Passion/interest

2/ Working conditions (hours and autonomy)

3/ Income level and social position

4/ 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.

- **Supportive elements**

Young people and their professions: dream and reality [25]: This study from Belgium shows young people expectations for their profession: autonomy for action, various and numerous contacts and the

[24] Bayer Facts of Education Survey, 1998 (http://www.bayerus.com/msms/news/facts.cfm?mode=detail&id=survey98)

[25]**Young people and their professions: dream and reality:** « Les jeunes sont plus précis dans la définition de leurs attentes vis-à-vis du métier. Celui-ci doit leur permettre beaucoup d'autonomie d'action, des contacts nombreux et variés et la prise de responsabilités. Le souhait d'autonomie se ressent aussi dans le choix du statut envisagé. Plus d'un jeune sur deux envisage d'être indépendant ou dirigeant-employeur. » (…) « Pour les aider à déterminer leurs choix professionnels, ce n'est l'avis ni des parents, ni des professeurs, ni des amis, ni des conseillers en orientation, qui influencera vraiment les jeunes, mais bien les contacts concrets avec le terrain. Un jeune sur deux dit que ce sont des rencontres avec des personnes travaillant dans le secteur qui l'intéresse qui influencera sûrement ses choix. Ils veulent l'avis de praticiens, de personnes expérimentées pour se faire une idée bien concrète du métier ou de la fonction qu'ils envisagent d'exercer. C'est donc l'expérience professionnelle qui compte : celle des autres, mais aussi celle que le jeune a lui-même engrangée au cours des stages effectués et des jobs d'étudiants. Les jeunes souhaitent d'ailleurs que les écoles, dans les actions qu'elles mettent en place pour les aider dans leur orientation professionnelle, leur facilitent ces contacts avec les professionnels de terrain. En effet, les 6 actions prioritaires qu'ils voudraient voir organisées sont, par ordre d'importance :
- des rencontres avec des professionnels en dehors de l'école
- des visites à la découverte d'entreprises
- des rencontres avec des écoles supérieures et universités
- des stages
- des rencontres avec des professionnels dans l'école »

opportunity to take responsibilities. More than half the respondents would plan to be self employed or head of company.

Les maths et les sciences n'ont-elles plus la cote ? CSRE 2003,(p89): This study from Switzerland displays criteria of importance for young people in the choice for a profession: independence in the profession, varied activities and self-fulfilment.

Pfenning & Al, 2002 (p 98) : Relating to the choice for studies and a profession, these authors show that the perception that young people have of S&T studies and careers differs on many point from what they are looking for (professional autonomy, variety of activities and personal fulfilment. Meanwhile, according to these authors, external motivations are on the way to loosing importance: the choice would be more and more pleasure-driven and less and less utility-driven)

Zwick et Renn 2000 (p 102): They point out that young people tend to choose in priority in function of their interest and search for pleasure. They generally choose to study the subjects they like rather than the subjects that will be useful for their career. Strategic reflection on the work market comes later and generally concerns more those that will become engineers and company managers.

Prenzel 2002, (p31ss): Emphasizes that interest in a subject is the main criterion for courses, studies and career choice. Cost, career prospects or possible income are also taken into account but as secondary elements of the choice making.

Talking about leaving - Seymour, E. & Hewitt, N. - USA - 1997

In this survey, about one third (29%) of switching decisions from S&T to non S&T subjects and 43,1% of all switchers' concerns reflect reservations about the kinds of work that will be available, and the lifestyles that these careers may imply. 21,1% of SME seniors students also expressed anxiety about these issues.

"S&M switchers, whose reasons for rejecting their majors included career and lifestyle concerns, gave more complex, diffuse reasons for their decision than did engineering switchers. They described their search for a balanced lifestyle, in which work was an important (but not the dominant) factor. They valued work for its intrinsic satisfactions and the social purposes it served, rather than for its material rewards. Some rejected the lifestyle that careers in corporate science (including those in the defence industry) connoted for them"

5.2. INTEREST AND VARIETY IN THE PROFESSION

The first criterion for choice of a profession mentioned by young people is passion and interest. This is a double sided factor as young people's attitude to S&T is very contrasted.

- **Supportive elements**

- CCSTI, France, 2004: "having an exciting profession" comes first as a factor of choice for a profession among high school students

- SAS, Norway, 2002: "having an exciting job" comes first as a factor of choice for a profession among 13 year old children

- Dream, Belgium, 2002: "Passion" is the second criterion for the choice of a profession, after "this profession corresponds to my abilities and competences".

Talking about leaving - Seymour, E. & Hewitt, N. - USA - 1997
"What students are looking for?"
"First, they sought work which was intrinsically interesting, and were often prepared to settle for lower material rewards in order to do it". "second, they looked for work that served a social purpose of which they approved"

"A dominant (and growing) concern among SME undergraduates was that the work available to graduates – particularly to those without a higher degree – would not be fulfilling, enjoyable, or have a worthwhile purpose. They worried that the only work available to them would be at low levels of responsibility and autonomy, or would demand time and commitment at the expense of other valued life interests".

5.3. WORKING CONDITIONS

5.3.1. Long hours and difficulties balancing work life with family and personal life.

Even if passion seems to be the first criterion for the choice of a profession, several studies show that the possibility of balancing working life with family life is mentioned as important by young people.

Certain types of scientific professions, such as in the research field, may be seen as too demanding to obtain this balance

- **Supportive elements**

Results from the surveys:

- **CCSTI**, France, 2004: the possibility to balance working life with family life comes second as a factor of choice for a profession among high school students.

- **SAS**, Sweden, 2002: "have more time with my family" comes second, for 13 year old children

- **Dream**, Belgium, 2002: "working at most 2 or 3 days a week" and "doing the least as possible" come among the least important values mentioned by the lower secondary students in this survey with respectively 60.5% and 64.3% saying it is "not much" or "not at all" important. They do not seem to fear heavy workload or time constraints as 82% say they don't particularly fear having to work long hours or on week-ends (47.4% not at all, 34.6% a little) and 92% say they don't particularly fear to have to comply with a rigid timetable (60.6% not at all, 31.2 a little). But on the contrary, having a good balance between private and professional life comes 5th with 89% saying it is "important" or "very important".

- Talking about leaving - Seymour, E. & Hewitt, N. - USA - 1997

"As we intimated in the previous section, switchers are also looking for what seems to them to be a healthy balance between their work and the rest of their lives"

5.3.2. Autonomy:

Young people strongly say they are looking for autonomy in their future profession. Some experts believe that they may have the feeling they will not find it in nowadays S&T careers. A first reason for that may be the evolution of the very nature of the S&T professions, that takes more and more the form of large projects with large teams. A second reason may be seen in the fact that many young S&T professionals (mostly science researchers and computing engineers) have to go through a first period of short term contracts and subordination.

- **Supportive elements**

Dream :Youngsters and their professions: dream and reality – Belgium – 2002. – Surveyed young people want their future job to give them autonomy for action: among their criterion for the choice of a profession 35.8% of respondents mention the opportunities to take responsibilities and 29.7 mention the opportunity to work alone. More than half the respondents plan to be self-employed.

Europe needs more scientists: “One of the features of SET careers nowadays is that, unlike before, they do not allow much room for individual autonomy until much later in life.”

5.4. INCOME LEVEL AND SOCIAL POSITION

The situation differs significantly between engineers and other technical trainings and more general and academic fields.

In some countries, young people consider that general academic S&T studies lead mainly to publicly financed jobs like research in publicly funded labs or teaching, which are perceived, often with reason, as less well paid.

In some countries (USA, France…), teaching, as an S&T career prospect, seems to be poorly valued.

Nevertheless, most adults would recommend a career in science to their own child or young relative.

Income level is generally considered as insufficient, especially in academia.

- **Supportive elements**

- **Talking about leaving** - Seymour, E. & Hewitt, N. - USA - 1997
  - an important minority (31%) of interviewed students that decided to leave S&T consider that “SME career options/rewards felt not worth the effort to get degree”
  - “teaching was consistently portrayed as an “alternative or “deviant” career, which a handful of switchers and non-switchers pursued despite the disapproval of faculty, family and peers”. “We commonly heard that more people would follow their inclination to teach were the pay or prestige of the profession better, or were it less time-consuming and expensive to undertake an education qualification on top of a baccalaureate degree.” “students also saw teaching as a form of professional activity that was undervalued by the wider community. It seemed to pay poorly compared with other options, and family and peers tried to dissuade them from choosing to teach” “There was no doubt in the minds of that fifth of our overall sample who had considered teaching as a career that their ambition was regarded as deviant by most of the significant people in their lives”
- **Woolnough B, Why students choose physics, or reject it** : ACOST study on pre-16 and A-level students (1990) showed that in the UK careers in science and technology were seen as having low status, relatively low pay and modest career prospects

EKOS: Most Canadians would recommend post-secondary studies and/or a career in science to their own child or young relative. Those with higher levels of science education are more likely to strongly recommend a career in science. (This could mean that the real careers are attractive as the one that are best informed are more prone to recommend them)[26].

[26]**EKOS:** 77% of Canadians would recommend a career in science to their own child or young relative; 84% of Canadians would recommend post-secondary studies in science to their child or relative. Note that Canadian with higher levels of science education are more likely to strongly recommend a career in science to their child or young relative: 87% of those with post-graduate science compared to 63% with less than high-school level science

Europe needs more scientists: "Even when they are fully established in permanent jobs, in academia and elsewhere, researchers are not highly paid in comparison with people of similar standing in other professions."

The "crisis of science vocations" and its causes - Observa : On the contrary, 81.7% of Italian science graduates currently employed claim to be very or quite satisfied with their salary ()

Woolnough Changing pupils' attitudes to careers in S&T "It was interesting to note that those who expressed an opinion about the salary and the status of jobs in science did so in very positive terms. For most students aged 11-16, jobs in science are seen as well paid, secure and of good standing in the community."

Survey on students' motivations toward science learning – national situation, Ogura (2005, in Japanese). Few students think that learning science relate to becoming wealthy. About 10% of students at grade 5-12 responded affirmatively to question 'Persons become wealthier by learning science.'

5.5. LIFE STYLE

Young people don't have a clear image of what S&T professions and professionals are. The lifestyle they perceive from the medias is not attractive to them.

- **Supportive elements**

Talking about leaving - Seymour, E. & Hewitt, N. - USA - 1997

"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 organizational 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".

"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."

"about one third (29%) of switching decisions from S&T to non S&T subjects and 43,1% of all switchers' concerns reflect reservations about the kinds of work that will be available, and the lifestyles that these careers may imply. 21,1% of SME seniors students also expressed anxiety about these issues."

"Choosing science at 16" (Munro & Elsom , 2000):
"The pupils' perceptions of the contrasting life-styles of "scientists and technologists" and of "management consultants and media people" were thought by teachers, and some pupils too, to play a significant role. "Lifestyle" was a recurring theme in the ambitions of the pupils in the 14-16 age-group, particularly boys"

5.6. STABILITY AND CAREER TRACKS

5.6.1. Job security

Massive layoffs made at the beginning of the nineties by many multinational companies and in many countries due to economical variations may have raised doubts among young people about S&T professions.

In some countries, among which are those with a high unemployment rate, job security is a major concern for young people (for instance Germany, Canada, France and Korea)

Some analysts believe that young people may choose engineering rather than academic ones to benefit from better job market situation. We do not have enough data to assess this hypothesis.

In research, S&T positions are often temporary and the competition is very strong, which causes insecurity, especially in the early stages of a career. The current trend is towards higher flexibility with more temporary positions.

There could be a conflict between the need for deeper specialization and the need for higher flexibility.

In S&T, specialization makes it more difficult to switch to other tasks in case of unemployment.

- **Supportive elements**

Pfenning & Al 2002: they point out that human resources policy in the economic world – the main activity field for engineers and science graduates- determines to a large extent the image of these careers and exerts an influence on young people. According to them, massive layoffs by large companies in the early nineties turned young people away from these professions.

Les maths et les sciences n'ont-elles plus la cote? CSRE 2003 p100

Europe needs more scientists[27]

Egeln/Heine 2005, Minks 2004 - Germany: Job security is a major motive, especially for engineering students as sharply rising unemployment among older engineers (45 and older) leads to skepticism about the sustainability of engineering skills.

5.6.2. A difficult start in the career

- **Findings**

In research, the professional integration process is long and difficult.

[27] **Europe needs more scientists** :
"Researchers become so identified with their specialities and so 'locked into' their established fields of research activity that they find it exceedingly difficult to move into other fields."
(…)"Traditionally, one of the most attractive aspects of a research career was stability of employment. After a strenuous period of doctoral training and competition for a post, a researcher could settle down for life in a university, a public research organisation, or a large industrial firm.(…) For various reasons, this situation has changed. Academic tenure comes later in a career, if at all, whilst large industrial companies are downsizing their in-house R&D facilities, and contracting out much of their SET work to smaller firms with much higher rates of labour turnover. Indeed, much of their strategic-applied research is being performed in universities by contract researchers with no long-term job security."

In a number of S&T professions, young graduates have to go through numerous temporary (computing) and/or under-paid contracts (research …)

- **Supportive elements**

Example of France: **Ourisson's report** shows that the early stages of science careers have became more and more difficult in France both because of income issues and because of few opportunities to do autonomous research. Three years after graduation, 18.4% of those having a PHD in science and 35.6% of those having a PhD in natural sciences still work under non-permanent contracts whereas only 4.1% of engineers are in the same situation.

Europe needs more scientists (European commission): "Postgraduate students, postdoctorates and junior academic staff are notoriously poorly paid, both relative to their contemporaries in other professions and absolutely in terms of the quality and quantity of the work they do." [28]

The "crisis of science vocations" and its causes - Observa : In Italy, three years after graduation, only 75% of Italian tertiary graduates in Maths, Physics and Computing Science have a permanent job.

5.6.3. Career mobility

In recent decades, career mobility, from one company to another and even from one field of activity to another has become the common pattern in many professions.

In many countries, this is not the case for scientists working in academia, which are closely linked to (dependant on?) their university or laboratory.

Even in other kinds of S&T professions, the importance of being specialized makes the opportunities for subject mobility low.

As young people have grown up in a rapidly changing world, these constraints on career mobility may be seen as a negative factor in the choice of a career.

- **Supportive elements:**

Europe needs more scientists[29]

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[28] **Europe needs more scientists** "The accumulation of personal debt is not untypical at this stage. This is because, although they have passed through a highly selective hierarchy of examinations, they are still considered to be apprentices to their craft. They are thus deemed to be sufficiently privileged by having the freedom to do the research that will be needed to make a good showing in the final competition for a tenured academic post. (…) a short-term, postdoctoral 'fellowship' is considered to be 'prestigious' in terms of future achievement, and thus to require scarcely any monetary incentive."

[29] **Europe needs more scientists:** "Nevertheless, 'established' researchers, especially in public-sector institutions, are often discouraged from moving elsewhere by 'tenure' and pension rights. As noted above, there are also very strong customary constraints on movement between disciplines. Upward or sideways career moves into quite different types of employment, such as academic administration, full-time teaching, professional consultancy, or business management, are not the norm. (…) Academic science is meritocratically open at its early stages, but it is very rigid and highly stratified overall, and has no regular procedures for upgrading its non-research personnel to responsible research posts in mid-career."

- **Minks 2004; Zwick/Renn 2000**: In competing fields (economics) the flexibility of carreers seem to be higher. In engineering specialisation and permanent technological and/or scientific progress makes it more difficult to switch to other tasks in case of unemployment.:

5.7. EXPOSURE AND COMMUNICATION

5.7.1. Knowledge of professions

Limited and uncertain knowledge of careers open to S&T students.

As an example, young people may misperceive the range of opportunities opened by science studies. First, the range of scientific professions is larger than most of them think it is. Second, many non-scientific professions use scientific knowledge and require science studies (like medicine requires chemistry and biology; and economy requires maths).

- **Supportive elements**

Euroscene report for Flanders, 2005 p6:

"The general perception of science and technology is characterized as a twofold problem:

- Sciences and related professions are largely unknown
- Technology is not unknown, but the profession of technician is largely unpopular "

"Outlook on scientific and technical professions" CCSTI Grenoble: the study shows that the surveyed young people (from lower secondary and upper secondary) do generally not have a precise knowledge of the career opportunities offered after science studies. When asked about the job opportunities opened by S&T studies, many of the surveyed young people do not answer at all or give a very vague answer (as an example mathematician as a job opportunity of maths studies). The subject for which job opportunities are least known is physics whereas the one for which they are best known is "life and earth sciences"[30].When given a list of professions and asked to say whether they are of a S&T nature, the results vary strongly, showing no significant trend. S&T professions are given as non-S&T and reverse. The same is true when asked about the S&T nature of the profession of persons familiar to the students.

Les maths et les sciences n'ont-elles plus la cote?: young people lack information on the utility of MST subjects and on further opportunities to study in these fields.

Talking about leaving - Seymour, E. & Hewitt, N. - USA – 1997: Both current and former mathematics majors complained that, from high school onwards, their advisors promoted mathematics as a flexible major which would open doors to a variety of careers. However, they had found difficulty in getting concrete information about career options, either from career counsellors or from

[30]**"Outlook on scientific and technical professions" CCSTI Grenoble:** « On a interrogé les informateurs sur les débouchés professionnels des 4 matières considérées pour l'enquête. Cette question a recueilli très peu de réponses. Qui plus est, celles-ci sont souvent vagues, composées de termes génériques (mathématicien par exemple). La diversité des débouchés des filières scientifiques est peu visible par les informateurs, y compris par les lycéens qui préparent pourtant un bac scientifique. Une analyse détaillée montre que ce sont les débouchés de la physique qui sont les plus mal connus et ceux des SVT qui sont les mieux connus. » p15

mathematics faculty. On every campus, we encountered a number of mathematics switchers (predominantly female) who were high achievers, both in high school and in college, but had been unable to find satisfactory career goals in mathematics"

5.7.2. Career guidance

S&T teachers are sometimes reluctant to advise their students about S&T careers. They say they do not have enough information and might give wrong advice.

We do not have explicit data on this point but this may be also the case for career guidance persons.

- **Supportive elements**

Choosing science at 16, *the influences of science teachers and careers advisers on students' decisions about science subjects and S&T careers* - NICEC project report - Munro, M & Elsom, D – UK – 2000. On the whole, science teachers did not feel able to keep up with the careers & employment in S&T: there was a "career person" to do this. The teachers were worried about giving incorrect information.

5.8. COMPETITION WITH OTHER CAREERS

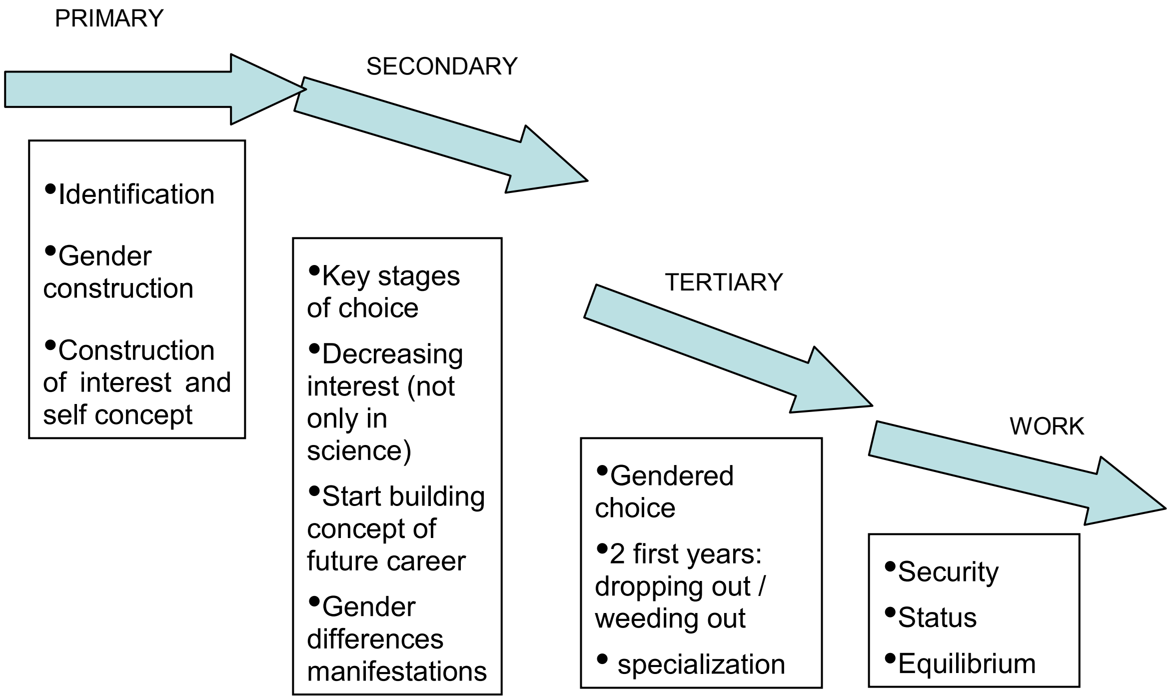
In some countries, a scientific major in high school is considered as an excellence criteria and opens valued opportunities outside the science field. Thus, science careers have to compete with the most valued other careers (health or business management, for instance)

For instance, in Japan, bright students in S&T courses often choose medical sciences or law and business courses at tertiary education level.

- **Supportive elements**

Ourisson's report shows that in France, young people with a S&T major in high school may prefer later on to choose medical studies or business studies that are as difficult as science but may have a better return on investment.
Results of survey on students' motivations toward science learning –Ogura & JST (2005, in Japanese)

6. S&T EDUCATION AND CURRICULA



This part of the report will consider each one of the three stages in the education process:

-Primary stage: no choice for children, science education is aimed at everyone. 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 positive attitude

-Secondary stage: During adolescence, young people often experience a decline in their interest towards studies in general. Yet, motivation seems to be depending 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.

-Tertiary stage: More rational criterion like forecasted gain and risk assessment.

6.1. WHAT YOUNG PEOPLE SAY ABOUT S&T EDUCATION & CURICULA

About their perception of the different fields:

"biology is fun, chemistry is dull and physics is difficult", maths are useful but difficult (UK, Choosing science at 16, NICEC project report).

About the attractiveness of S&T education:

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 answers and 55% put "scientific subjects are too difficult" among their three first answers.

According to a Korean survey on primary and secondary education, math and science are both the favourite and the most disliked subjects among students. Students who pick math and science classes as their favourite ones say the main reason is these subjects are "interesting". Students who most dislike math and science classes indicate the difficulties in understanding as prime reason.

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

- **Supportive elements**

Eurobarometer: Europeans Science & Technology, 2001

• Overall positive perception of science and technology (despite recent crises and the fact that science is also perceived as a kind of Pandora's box)
• Europeans have high expectations about science and technology but...
• Science and technology are no longer considered a panacea for a series of problems
• Interest in science slightly lower, in relative terms, than in 1992 (sport scored higher than science)
• The perception of science is no better or worse among young people than among the public as a whole
• According to the people interviewed, causes for declining interest in scientific studies and careers are as follows: science
classes at school not sufficiently appealing (59.5%); scientific subjects too difficult (55.0%); young people less interested in
scientific subjects (49.6%); career prospects not sufficiently appealing (42.4%). 60.3% of Europeans feel «the authorities should try to resolve this situation
•Only 30% of respondents feel that the disaffection for science studies could stem from a poor image of science in society.»

National Survey conducted by Korea Science Foundation, 2003

• The total number of students who answered the survey was about 1,670,000 (among them were 900,000 primary, 450,000 lower secondary and 240,000 upper secondary students). It was about 22% of the cohorts.

• About 1/3 of the students of both primary and secondary education choose math 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 of why students like math and science classes, those who pick them as their favourite ones indicate the major reason is that the subjects are interesting. The rates were 45.7% for primary, 62.3% for lower secondary, and 72.1% for upper secondary school students. Other reasons chosen were that they are easy to understand, or that they get high grades, or that teaching methods are interesting.

• Also about 1/3 of the students choose math and science as their most disliked subjects. The rates were 26.1% for primary, 28.3% for lower secondary, and 36.8% for upper secondary school students.

• To the question of why students dislike math and science classes, those who pick them as the most disliked subjects indicate the main reason is the subjects are difficult to understand. The rates were 51.9% for primary, 57.3% for lower secondary, and 56.0% 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 of 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. It's quite significant that the satisfaction rate diminishes rapidly as the education stage goes higher. To improve math and science classes, 72~80% of the students of all educations stages suggested to promote hands-on experiment and easy-to-understand curriculum, with almost equal votes.

6.2. ISSUES REGARDING ALL PROCESS STAGES

6.2.1. Conflicting double aim: fuelling the demand for a specialist elite and the need for a scientifically-literate citizenry

The primary and lower secondary curriculum answer to a double aim.

The first one is to give the basic knowledge of S&T necessary for all citizens as well as making everyone familiar with scientific thinking and developing curiosity and interest towards science.

The second one is giving the students that are to become the future S&T professionals the knowledge they will need and selecting them.

The first one involves more participative approach and focuses on interest whereas the second aim involves teaching more conceptual and challenging material.

The difficulty is to use an appropriate mix of both types of teaching methods and subjects to raise interest without giving up the necessary building of a corpus of knowledge and the selection of the future scientists. This mix is specific to each stage.

Some authors suggest that selection and specific education for future scientists is to be postponed to upper secondary school and that before, the only aim should be the general one.

- **Supportive elements**

Carter L. & Smith C.: "The role of research in reconceptualising science education for the 21st century".

6.3. PRIMARY EDUCATION

6.3.1. Relative weight of theory and practice

Particularly for the younger children, practical and experimental approach to science subjects is considered as the more attractive.

But, as for today, this approach is not efficient regarding the assessment system, which rely more on theoretical content. Actors often have to arbitrate between those activities that increase interest and motivation and those that increase the chance of success at the evaluation.

Theory-oriented teaching, often of the type of “talk and chalk” and the absence of the necessary steps to get well-acquainted with sciences, like hands-on experience and discussions in school may discourage children’s interest towards sciences.

Possible causes:

- The courses are often evaluation driven and the evaluations does not require practical knowledge

- The teachers may not be comfortable with their subject and with hands on situations

Time pressure and heavy course content prevent teachers from putting emphasis on the activities that could stimulate interest (the course is aimed at the nearly unique target of performing at the assessments).

- **Supportive elements**

Osborne (GB): his work showed the critical importance that pupils have the opportunity to experience physical phenomena and engage themselves in relatively autonomous discovery. He promotes modern active methods (constructivism) for science learning. For him, what keeps teachers from using such beneficial methods is the pressure coming from the evaluation process. He regrets that evaluation emphasizes remembering of facts rather than the ability to manage information properly and with autonomous thinking. [31]

Euroscene report for Flanders

6.3.2. Other causes (local, low-impact, non-actionable, or with insufficient supportive elements)

- **Equipment:**

In some countries, Infrastructure at schools, especially for technology, may be insufficient. (Euroscene report for Flanders).

PISA 2003 school principals’ perception on school laboratory

- **The impact of fathers’ implication and the number of single-parent families.**

Cockburn (1988) : He explains that mothers have lower influence on this process because the children tend to attribute to mothers what is linked to the use of technical devices whereas they attribute to fathers what relates to invention, development and maintenance of theses devices; Then, when it is about techniques, children turn more to fathers. (quoted in Les M et les sc n’ont-elles plus la

[31] **Pupils’s views of the role and value of the science curriculum : a focus-group study J. Osborne, S. Collins, International journal of science education, 2001: “**The privileging of science over technology, within the English and Welsh National Curriculum, is akin to introducing the grammar of a language before practicing its use.”(…) “Rather, the findings of this research would suggest that courses that privilege technology over science – introducing the applications first such as Salter’s Science should be the natural first choice for any school” (…)“(our data) confirm(s) the critical value and significance to pupils of the opportunity to experience physical phenomena first-hand – the opportunity to engage in apparent autonomous discovery” (…)“students welcomed the active learning and the project work being encouraged in some other, non A-level, courses”(…) “It is highly anomalous, that in an age when society increasingly places a premium on the higher order cognitive abilities to retrieve, sort and sift information, that such curricula continue to place an emphasis on lower order abilities of recall and comprehension of basics concepts”

cote ? p89); In many countries the increase in divorce rates has resulted in an increase of single-parents family, among which most are composed of mother and children. Then these children are probably less exposed to the father's influence.

6.4. SECONDARY EDUCATION

"I know all about elements and compounds and mixtures and that atoms have little circles and dots and how to use a Bunsen burner but I don't know what that has to do with anything. "

(quote from a 15 year old schoolgirl, Levinson and Thomas, 1997 p. 1).

6.4.1. Relevance to things young people care for

To become interested in a subject, secondary school pupils need to feel the relevance of the subject to their own world. This is far from being always the case.

- **Supportive elements**

Osborne J. (GB):

- - Technological applications, which could be the link between science and everyday life, are presented as an annex to the teaching of raw facts.
- - Biology is one of the scientific fields that children like most, perhaps because the relevance to children's life is obvious.
- - Teaching of contemporary science could be a way to increase the relevance of S&T to children's everyday life and thus to increase their attractiveness [32]

Osborne J. (GB) - Attitudes towards science:
"Whereas biology, particularly human biology, was relevant and pertinent, addressing pupils' self-interest in their own bodies and concerns about health and disease, the relevance of the physical sciences was difficult for students to identify." (…) "In addition, the technology school science dealt with, the Haber process and the Blast furnace, was the technology of yesteryear and not that of their lives – the silicon chip, modern materials, informatics, and medical imaging."

Woolnough B, Why students choose physics, or reject it and ACOST study on pre-16 and A-level students (1990): This effect on attractiveness is even stronger with girls [33]

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[32] **Pupils's views of the role and value of the science curriculum : a focus-group study J. Osborne, S. Collins, International journal of science education, 2001** :"Physics and chemistry, in contrast (with biology), have less points of contact with pupils experiences and, even when technological applications are introduced, they are often done as a postscript whose illustrations appear archaic to some pupils." (…) "Vital to any such course, as well, would be a component that allowed for the exploration of aspects of contemporary science,(…) essential to constructing a connecting thread between school science and the 'real' world of the adults, endowing the subject with a relevance that no other mechanism can."

[33] **Woolnough B, Why students choose physics, or reject it and ACOST study on pre-16 and A-level students (1990):** "Girls in particular reacted against the impersonal and abstract nature of the physical sciences at A-level, wanting their studies to have relevance to their lives and to environmental issues".

Zwick et Renn (2000, 109), criticize the way physics is taught, all the way through secondary education, as too abstract and theoretical, too based on mathematics, with a too marginal importance given to technique and with no relation to everyday life.

Ourisson's report states that young people may think that science studies are far from the "real" issues of contemporary world.

A common denominator for many pilot projects is to better integrate the application and everyday life usefulness of S&T with the learning of scientific basics.

What young people like to learn about - **SAS** Study of 13 years-old

Egeln/Heine 2005, Prenzel 2002, Muckenfuss 1996 (Germany)**:** the evaluation of school teaching is rather bad. Especially those who decide against science or engineering studies tend to see sciences courses as boring, complicated, incomprehensible, deterring and not relevant for everyday life.

6.4.2. Intrinsic difficulty (?), confidence and didactic issues

- Maths, S&T are generally considered as difficult subjects.

- The more students doubt of their possibilities, the more they may fail. At the opposite, "Students who believe in their abilities make successful learners"(PISA)

- Considering the mediocre position maths and physics have on the popularity scale, even more so for girls, many researchers criticize the way science teaching is done.

- Pfenning et al. (2002, p89) believe that the decline in the number of young people studying sciences comes from their reputation of being difficult and with a high drop out rate.

- **Grades issue**: in some countries, the return on investment with respect to the grades is considered better in language or socio-economical subjects than in S&T (Germany, UK). There is no consensus on this point, though, in some countries, there seems to exist a general perception that it is much more difficult to obtain good grades in MST subjects than in other subjects. This could deter young students from choosing these subjects as good grades are necessary to enter good universities.

In addition, a low level of grades may impact the confidence students may have in their own abilities. (to address this point, one may consider reengineering the gradation system or lowering the level)

- **Supportive elements:**

For **Schecker & Klieme** (in Hermann 2002 p66), the subjective feeling of ability is a decisive factor for subject choice in early secondary education.

Choosing Science at 16":" common, and not misplaced, perception that physical science subjects are more severely graded at A-level …."

"High School and beyond", survey conducted by the Department of Education, and quoted in the NSF Report "The state of Academic Science and Engineering" (1990), in Speaking about leaving [34]

Woolnough B, Why students choose physics, or reject it: ACOST study on pre-16 and A-level students (1990). [35]

[34] **Speaking about leaving** "Students were found to switch out of SME majors into other majors for two main reasons: 43% said they found non-SME majors more attractive, and 31% stated that they found the work "too difficult" (p 8-9)

Woolnough B., Factors affecting students' choice of science and engineering:
" The potential scientists and non-scientists had significantly different views on a number of aspects of their science activities. The scientists valued more the opportunity to plan their own experiments, thought that learning scientific facts and theories was more important, thought that extended practical projects showed them what science was like and got them more interested in it, valued the well-structured lesson more and had found involvement in S&T competitions to be more good fun (perhaps the non-scientists had not experienced them). There was some evidence that the non-scientists had had less good work experience in science-based industry, which could turn people off jobs in Science and engineering.

Marsh, 1986: "Students' academic self-concept is both an important outcome of education and a powerful predictor of student success. Belief in one's own abilities is highly relevant to successful learning"

PISA: students self confidence in mathematics is low and this may significantly affect their ability to learn. [36]. The study shows that students who are less anxious perform better regardless of other characteristics… [37]

Giordan & De Vecchi : Based on their own work as well as on European and American surveys, they observe that teaching of S&T notions is often not effective. What is learned is only superficially understood and quickly forgotten. For them, the problem comes from the fact the previous knowledge and children's beliefs are not taken into account in the teaching process. (Giordan & De Vecchi 1994, p11)

Euroscene report for Flanders

Outlook on scientific and technical professions (CCSTI Grenoble): science studies are perceived as long and difficult.

Ourisson'report on French situation shows that science studies are considered, with reason, as difficult, long and demanding.

- **Comments**

- Some may consider that Science is intrinsically difficult. From this point of view, the analysis must be focused on how young people react to this difficulty, and which factors linked to this difficulty are key factors in deterring them:

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[35]**Woolnough B, Why students choose physics, or reject it** "The sciences were often perceived as being difficult subjects, requiring particular skills which you had either got or you hadn't". About sciences: "they commented on the heavy content demands of the courses and the sterile, impersonal nature of much of that content."

[36]**PISA** "A third of males and half of females think they are no good at mathematics" "Students who believe in their abilities make successful learners… but two-thirds of students find some of their mathematics work too difficult and half say they do not learn mathematics quickly…" (…) "For most of these questions, comparatively large gender differences are apparent. For example, while on average across OECD countries, 36 per cent of males agree or strongly agree that they are simply not good at mathematics, the average for females is 47 per cent. In Italy, Japan, Korea, Norway, Poland, Portugal and Spain and in the partner countries Brazil, Hong Kong-China, Indonesia, Macao-China, Thailand, Tunisia and Turkey, between 50 and 70 per cent of females agree or strongly agree with this statement (…) The comparison shows that students in Canada, Denmark, Germany, Mexico, New Zealand, the United States and the partner country Tunisia have the greatest confidence in their mathematics abilities. Students in Japan and Korea and in the partner country Hong Kong-China have the lowest self-concept. In almost all countries, there is considerable variation between males and females and in all countries males tend to show statistically significantly higher levels of self-concept in mathematics than females. This is particularly so in Denmark, Germany, Luxembourg, the Netherlands and Switzerland and in the partner country Liechtenstein." p 132-133

[37] **PISA:** 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. p 148

- is the new generation risk-averse?

- is the new generation less tolerant to effort?

- is the new generation less tolerant of failure (social standing, unemployment pressure…)?

- does the value for work have a lower status than it used to have, resulting in disrespect for those working hard?

- An interesting point is that there have not been reported any decline in young people interest in other difficult and demanding activities such as arts or sport activities. And yet, sport practice and competition are difficult and demand heavy efforts and workload too.

- Others consider that science is not intrinsically difficult and that didactic and curriculum adjustments may reduce its perceived difficulty. Although the reduction of unnecessary difficulties would not cause any outcry, the debates are recurrent on the pertinence of lowering the standards.

- Some consider that the difficulty of S&T subjects has its own value in developing young people's cognitive abilities, and strengthening their will and selecting the more able.

6.4.3. The kind of ability that is valued

Secondary education students in some countries complain about the type of skills that are developed and valued in science courses.

Instead of putting the emphasis on deductive skills, problem solving and cooperative working, that both pedagogues and students consider as higher order abilities, the main emphasis is often set on learning raw facts and training to complete basic exercises

Possible cause: Quantity of what is taught - excessive and increasing content base that leaves no time for upper order skills

- **Supportive elements**

Woolnough B, Why students choose physics, or reject it: ACOST study on pre-16 and A-level students (1990) [38]

Choosing science at 16, NICEC project report (UK)[39]

Osborne papers, UK[40]

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[38] "The feedback from the students concerning their A-level courses, in physics and chemistry in particular, was especially worrying. They were perceived as being very difficult, heavily content-loaded, very dull and demanding passive reception rather than active involvement with the learning process. Coming after their GCSE courses, with their emphasis on process rather than content, and ways of using information rather than mere acquisition of knowledge, the A-level courses were a rude shock."

[39] "The national curriculum was seen by science teachers in all the case-study schools as placing time pressures on GCSE science courses and also as squeezing out extra activities designed to motivate pupils and increase their awareness of the applications of science in society and in the workplace". (…)"[stringent health and safety regulations] and the constant requirement of assessment, were thought by many staff to have removed some of the fun and interest from science classes"

[40] " In a climate of 'high-stakes' assessment where many teachers feel compelled to cover the entire content to maximize their pupils chances of success, the experience is too rushed, forcing teachers to use techniques such as 'copying' (…) The other unintended effects is the elimination of anything extraneous of a time consuming nature such as practical work or opportunities for discussion. Yet it is exactly the components that are highly valued and prized by pupils for the interest they generate in the subject."(…) "From the evidence collected, it appears that pupils have to make subject choices which can crucially affect their future options at a time when their motivation in science subjects is reducing and their perceptions of what for many are largely invisible careers are very hazy. They are also at an age when peer-group pressure is very strong and when subject and career choice is not the highest priority amongst other teenage concerns such as image and lifestyle"

6.4.4. Heavy content

In some countries, through years, with the development of scientific knowledge and the increasing needs for S&T knowledge in society, the curriculum has continuously gained content. The current load may have a negative effect, putting too much pressure on both teachers and students

6.4.5. Other causes (local, low-impact, non-actionable or with insufficient supportive elements)

- **Equipment and support staff:**

In some countries, equipment may not be sufficient in quality and quantity.

Support staff also is of great importance. When there are not enough of them, teachers often have to substitute for them. This supplement of work, generally considered as unattractive to them, may result in teachers lack of motivation and reduction in the practical work done with students[41] (Sir Gareth's report, UK)

- **Coherence between subjects:**

In some countries, there seems to be an issue of coherence between the subjects, especially in secondary education. Subjects tend to stand on their own, because of the way teaching is organised (subject teachers). (Flanders – Euroscene report).

- **Identification**

Students and teachers agree on the fact high school students often choose their options according to the feeling they have towards their teachers (in order to choose some of them or to avoid some of them). For sciences, students and their family often do not know much about career opportunities and can not imagine what a scientist's everyday work life may be. Then, they are inclined to identify sciences to what they get to know through their studies and thus, the teacher figure is particularly strong. Supportive elements: Newtonia

- **A sharp decrease in interest:**

"Various studies have shown that students' interests in science decline sharply during secondary schooling (Rosier and banks 1990, Baird and Penna 1992, Baird 1994) Quoted in "enrolment trends in school science education in Australia". Dekker& de Laeter (cause: quality of the science education provided and/or distracting influence of the transformations due to adolescence?)

- **Top-down curriculum design:**

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[41] Sir Gareth's report. "poor environments": "only just over a third of school science and D&T (Design and Technology) laboratories in secondary schools are estimated to be of a good standard or better"(…) "pupil-to-staff ratio in practical classes is higher than in (…) many countries"

Europe needs more scientists: "The education curriculum is still designed 'from the top down', as if entirely for the ten-year process of generating successful doctoral candidates. But the students who actually complete this course comprise less than 10% of the pupils who voluntarily enter science courses at secondary school. Little account is taken of the career and societal aspirations and circumstances of the remaining 90%."

6.5. ISSUES SPECIFICALLY LINKED TO UPPER SECONDARY EDUCATION

6.5.1. Competition with other subjects and the broadening range of subjects

Wider range of available courses.

Recently, in many countries, the number of available subjects has strongly increased, thus decreasing the share of each one, among which are science subjects. Moreover, young people often have a taste for novelty and thus these new subjects may benefit from it.

Some experts question the fact that subjects have to be chosen at the wrong period in the young person's development as it is precisely the time when the lowest interest towards S&T is shown.

- **Supportive elements**

UK, Choosing science at 16, NICEC project report[42]

Woolnough B, Why students choose physics, or reject it: ACOST study on pre-16 and A-level students (1990).[43]

6.5.2. Courses choice/ advice to students on which courses to follow

The careers advisers are not always well acquainted with science subjects and science careers

Science teachers may feel uncomfortable with giving advice on careers as they may be worried about giving incorrect information.

This may result in a lack of information among young people as regards to S&T further studies and careers

- **Supportive elements**

Choosing science at 16, NICEC project report (UK)[44]

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[42] "common, and not misplaced, perception that physical science subjects are more severely graded at A-level"(…) "Wider range of "new" A-level subjects now on offer (particularly those with apparent vocational connections) were also thought by science teachers to disadvantage the traditional science subjects"

[43] Woolnough B, Why students choose physics, or reject it: "The structure of the 16-19 curriculum in England and Wales, in which students are forced into premature specialization by having to choose only three or four subjects, came in for much criticism from the students and the teachers. It was only those students with a high commitment to science by the age of 16 who opted for the sciences at A-level; others who were uninterested or agnostic towards science made irreversible choice of subjects which, subsequently, precluded them from a career or HE course in science"

Sir Gareth's report[45]

Rapport Galland (France) shows a lack of information about careers among students. [46]

Les maths et les sciences n'ont elles plus la cote?: young people lack information on the utility of MST subject-s and on further opportunities to study in these fields.

Very vague image of tertiary studies among freshman in Wallonia (**Discry-Théate**; 1998)

- **Comments**

The impact of parents' advice is not clear. Some studies like CCSTI put it at the first rank, while others, like Dream show a weaker impact.

6.5.3. Disconnect with "real" S&T

This issue relates to both lower and upper secondary levels but with probably a stronger impact on upper secondary students.

Some students have the feeling that what they are taught lacks relevance to what they consider as "real science" and what scientists really do.

The link most young people have with "real science" is through media. So real science is more about cutting-edge subjects and (non stabilized) new knowledge, whereas what is taught is consensual and well established (and thus often older) knowledge.

- **Supportive elements:**

Carter L. & Smith C.: "The role of research in reconceptualising science education for the 21st century". "Textbooks used convey nothing of the flavour of the "non-scientific" human struggles needed to arrive at consensual scientific knowledge, of the confusion, uncertainties, frustration and seredipity of the scientific method (Boulton and Panizzon, 1998; Cunningham and Helms, 1998). They largely present scientific truth and its production as revealed and indisputable, bearing little of the cultural fingerprints used in its generation."

Heinz Durner points out shortcomings in German gymnasiums teaching and concludes that "this is important to observe that S&T discoveries of these last decades are not sufficiently mentioned and taught in gymnasiums nowadays" (Les Maths et les sciences n'ont-elles plus la cote ? p93)

For **Badgasarjanz,** the economic, social and technological evolution is transforming S&T careers. These activities are losing some specificity from their subjects and disciplines and are more focused on methodology and knowledge processing. [47]

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[44] "Only 10% of the careers advisers in the survey had any science and engineering background at degree level.(…) The responses also highlighted the lack of systematic training and updating in occupational information now available to career advisers." (…) "On the whole, science teachers did not feel able to keep up with careers and employment in science and technology: there was a "career person" to do this. The teachers were worried about giving incorrect information."

[45] "negative image of, and inadequate information about, careers arising from the study of science and engineering"(…) At school and further education levels, "careers advice" : "pupils often view the study of science, mathematics and engineering as narrowing their options, rather than broadening them" (…)"careers advisers often have little or no background in the science"

[46] 63% of student say they were missing information as to courses choices in France in 1995 (Galland)

[47] Selon Badgasarjanz, l'évolution technologique, économique et sociale transforme comme suit les professions scientifiques et techniques: ces activités perdent une partie des spécificités propres aux disciplines considérées pour inclure un point de vue dynamique, utilisant l'informatique pour résoudre des problèmes techniques complexes. Il s'agit d'intégrer dans la réalisation de nouveaux produits les besoins du client, le potentiel technologique des fournisseurs, la connaissance des processus de fabrication les plus rentables, les techniques et les compétences spécifiques de l'entreprise, ainsi que les acquis scientifiques et les tendances décelables du marché. Et la compétitivité est aussi le résultat de processus de communication intensifs,

6.6. TERTIARY EDUCATION

6.6.1. The need for more professional/"soft" skills: a mismatch between what is taught and what is needed on the job market?

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…

In many cases, S&T curriculum do not include activities designed to build such skills.

More precisely, traditional type of S&T studies do not include that aspect whereas more contemporary or renewed ones tend to include it. Physics, Mathematics and chemistry are among the subjects mostly taught the traditional way and are precisely the ones that most suffer from decline.

This mismatch between what is taught and what is actually needed to become an effective S&T professional may be perceived by young people who will tend to choose disciplines that encompass the needed professional/"soft" skills.

- **Supportive elements**

Alumni survey conducted by the Radboud University.

Recruiting Female Students to Higher Education in Mathematics, Physics and technology: « Higher education is supposed to provide society with well- educated scientists. But the demands of society are rapidly changing. In the public debate it has been proposed that future mathematicians, scientists and technicians need a much broader education than is currently offered within universities and university colleges. Skills in handling complex problems of an interdisciplinary nature, competence in co-operating with others and in presenting scientific knowledge orally or in writing are qualities which are highly appreciated in the labour market but less highly valued within the current educational practices of mathematics, science and technology. »

Germany**: Bargel, Ramm, Multrus (2001), Minks 2000, 2004** : Engineering studies (at university) are 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 an modern economy find this topics neglected in engineering studies. This weakness discourages especially women from engineering studies.

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associés à l'aptitude à travailler en équipe, au maintien de l'avance et à l'exploitation systématique du capital de savoir. Cet auteur appelle par conséquent l'université et l'économie à intensifier leur dialogue afin de dépasser les clivages culturels qui se dessinent. Il est essentiel que l'enseignement universitaire dispense des compétences sociales et les principes d'une pensée en réseau (quoted in les maths et les sciences n'ont-elles plus la cote ? p100)

6.6.2. What makes S&T studies "hard"?

6.6.2.1.The integration process (the first years)

In some countries, students would face significantly more difficulties to positively integrate universities in S&T disciplines than in others. The gap would possibly be too large between Secondary and Tertiary level requirements. This would be one of the causes for high drop out rates

- **Supportive elements:**

Sir Gareth's report[48];

Porchet's report on France states that science DEUG (two year academic degree) suffers from its reputation. Among public opinion, science DEUG means: impersonal, overcrowded rooms, and absence of a professional track. He states: "S&T DEUG is to blame. It must adapt to students' expectations or its number of students will keep on decreasing".

Many S&T students take remedial courses in the US (source: Science and Engineering Indicators, 2002, 2004)

6.6.2.2.Other specificities in S&T studies?

These specificities are given by two studies on what students find hard with S&T studies:

- Absence of sense of community "competition was one factor, but that there was no debate or discussion possible was quite another"

- The missing overview "the problem in vertical subjects, of course, is that the destination is nearly incomprehensible until it is reached".

- The tyranny of technique "the class consisted basically of problem solving and not on any interesting or inspiring exchange of ideas." "for our tier, the tyranny of technique robbed them of the profound intellectual experience they had expected from science".

- Examinations/ narrow skills testing on examinations " The way an instructor operationalizes the goals for the course is not simply to speak them or to put them in a handout but to incorporate them in into his exams. While (the professor) was talking concepts his exams were testing numerical solutions. And he probably never realized what the students knew very well, namely that the "concepts" and the "history" didn't really count."

- Language "while professors already "think in notation", their students are having to translate formulas and expressions particular to the field into language they can understand and the back again."

[48] "increasing modularisation of A-level courses" (…)"difficulty in making the transition from studying at A-level to degree level in these subjects"

▪ Excessive pace: High-achieving non-science postgraduates in Tobias' (1993) study cited excessive pace and the representation of science as rigid and uncreative as the main contributions to making science a hard subject[49]

- **Supportive elements:**

Paper from Sheila Tobias (1993): **What makes science hard?**

Seymour, E. & Hewitt, N.: **Speaking about leaving**

6.6.3. Over - specialization:

- **Findings**

S&T studies are considered by young people as specialized studies and narrow subjects whereas many look for subjects that include a larger range of fields.

Many young people see more comprehensive studies as more fulfilling.

Also, in a fast evolving world, in which the future seems mostly unpredictable, some young people may be more secure with larger spectrum of competences and fields of knowledge.

- **Supportive elements**

Studies show that a large percentage of students try to avoid a too strong specialization in their studies. S&T courses may appear as too specialized.[50]

6.6.4. Selection and drop out rate

In many countries, in S&T (among which, Science more than Technology) are among the disciplines where the drop out rates are the highest (generally Maths, Physics and Chemistry)

Such high drops out rates have two mains consequences:

- It mechanically reduces the production of S&T graduates

- It discourages students to take S&T studies (called "Success expectancy": Knowing that the success rate is low, young people tend to choose other studies)

One of the reasons for such drop out rates could be that in some countries, over the last decades, university has been challenged by a shift towards mass studies. The young people entering university now, in some countries such as France, are more often from lower class and are academically less selected than it used to be.

In addition to a "passive" phenomenon of high drop out rates, in some higher education institutions, an active "weed-out" process is operated to select the most able students over the first few years. This phenomenon would be more prevalent in S&T than in other subjects and would have a double impact.

[49] The formation of science choices in secondary school

[50] When asked to the way they decided their courses at university, Belgian students answer they did it first on the basis of their interest towards the subjects and second on the basis of a desire to take a large variety of subjects and to avoid overspecialization. (Newtonia)

First, those who failed may spread out a negative image of science. Second, the selection would over-emphasis abilities such as self-confidence and resistance to pressure rather than purely assess the main cognitive abilities.

- **Supportive elements**

Talking about leaving[51]

Beaud S. , 80% au bac …et après?

As an example, for the **French S&T DEUG** (2-year degree), the success rate in two years is only 40% and in 3 years and less than 70%. The success rate is far better in other kind of studies like the vocational 2 year diploma named DUT: in physics/ chemistry, the success rate in 2 years is 66%, and in 3 years or less it is 89%. Knowing that the students with a DUT can follow on at university for longer studies, the fact to choose against DEUG is totally reasonable.[52]

Les Maths et les Sciences n'ont-elles plus la côte?: context for studying S&T would be discouraging.

Pfenning et al. (2002, 89) consider the high drop out rate in technical subjects as one of the causes for the disaffection that affects them.

Rand: "in all countries student retention in S&T is less (higher drop-out) than in other subjects

Heublein, Schmelzer, Sommer: Studienabbruchstudie 2005 (Germany) – They report very high dropout rates in science and engineering at university level.. According to a study on dropout and change (basic year: graduates 2002) only 45 % of entrants in physics and 42 % of entrants in chemistry finish their studies in the chosen field, while for other disciplines the rates are: computer science: 43 %, biology: 68 %; mechanical engineering (university): 48 %, electrical engineering (university): 49 %.

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[51] "the loss of 40 to 60% of a group of students with higher than average abilities within two years of taking their first college science or mathematics" (p391- 392)
"On the basis of their relative perceived significance, we posit that problems which arise from the structure of the educational experience and the culture of the discipline (as reflected in the attitudes and practices of SME faculty) make a much greater contribution to SME attrition than the individual inadequacies of students or the appeal of other majors"
" The assumption that most switching is "appropriate" obscures the loss of two groups of students whom SME faculty might prefer to retain. They might be described as the "more pulled than pushed" and the "more pushed than pulled". The first group includes very able, often multi-talented, students who have a strong interest in science and mathematics and would have stayed had the teaching been more stimulating and the curricula more imaginative. Although they are drawn to majors which promise a fuller educational experience, they retain their scientific interest and modes of thought and seek ways to combine these interests with their new majors and/or career plans. These students expressed ambivalence about switching and harbored thoughts of resuming their scientific studies at some future date. They attributed their decision to leave almost exclusively to the poverty of the educational experience created by the weed-out system. (…) The second group of students (…) are those who feel they have the ability to complete an SME degree, were adequately prepared, and entered their SME major largely on the basis of interest. They become discouraged by poor teaching and aspects of the wee-out process and, although they would prefer to stay in the sciences, they move into majors which they regard as a poor compromise. These are among the most angry, regretful and frustrated of all the students whom we interviewed. They felt their choice of an SME major had been appropriate, and that they could have completed it, given some faculty support and a less cut-throat atmosphere. The accounts of many women and students of color who switched could be described in this manner. Though we, of course, encountered students whose switching was "appropriate" in that they had chosen unwisely, were under-prepared, or did not (by their own admission) work hard enough, our data lead us to hypothesize that, on every campus, there are substantial numbers of able students who could be retained in SME majors were appropriate changes made in departmental practices."
"a pedagogical style dictated by weed-out objectives" (p394)

p2: "A 1987 National Academy of Science discussion paper concludes: "There is still movement into the mathematics, science and engineering (MSE) pipeline during the college years. However, at each stage, the net effect of the movement in and out of the pool is loss. The cumulative impact of these losses is substantial. Over 50% of the high school seniors surveyed dropped out of the MSE pipeline by the end of their first year in college. Some returned later on. However, by college years, only 35% of the high school seniors who planned on MSE majors had stayed with their plans. This suggest that, during the college years, more attention should be paid to preventing migration out of science (p29)"

[52] Repères et references statistiques – 2004, French Ministry of Education

This is far under the general average of 61 % successful entrants at universities which mixes very high (e.g. medicine: 86 %, legal studies: 73 %) and lower success rates (economics: 56 %, cultural studies: 31 %, social science: 32%).
At universities of applied science the figures are better, but even here the highest drop out rate can be found at computing (55 % success) and electrical engineering (60 % success).

Denmark: The problem of low completion rates/high drop-out rates among science students is reported to be very significant in Denmark. The completion rate level was particularly low when the "mass educational system" expanded in the period from 1960-1975. Particularly since 1985 the trend has shown a higher completion rate/lower drop-out rate. Compared to all university programmes, however, the drop-out rate in science is still high and considerably higher than the average. The drop-out rate for mathematics/physics/computer studies is still around 60 %, whereas life science is closer to 40 %.

6.6.5. A general trend towards profession-oriented studies?

Both academic and vocational studies are integrated in our study. Nevertheless, as we see that the more important decrease is in some high theoretical-content academic fields such as maths, physics and chemistry, we consider it important to analyse the relationships between these two.

Some young people's strategy would to avoid general/academic studies at the university and prefer vocational training / technical studies in order to improve the chances of obtaining a job as soon as possible. Indeed, in subjects such as those mentioned above, young people see few opportunities of getting a job before attaining master level or even PhD level degree.

This could help explain the decline in attractiveness of subjects like maths/physics/chemistry.

We use a large & comprehensive sense of vocational studies here, including all profession-driven curricula without prejudice of the level of the training. As an example, engineering studies are included.

- **Supportive elements**

Woolnough B, Why students choose physics, or reject it: ACOST study on pre-16 and A-level students (1990).[53]

Students tend to prefer courses where they can enter the job market at various stages, which is not the case for some of the S&T traditional curricula. **J. Dercourt's report** (France)

6.6.6. Other local, low-impact or non-actionable causes

__**Equipment**__

The HE Funding Council for England estimates that about half of all teaching laboratories are in urgent need of refurbishment (GB. Sir Gareth's report)

[53] "In contrast with the work their supposedly less able friends were doing in vocational, BTEC or work experience courses, the A-level content dominated courses were seen as increasingly unattractive. The hard divide between academic and vocational courses was seen as untenable, the A-level sciences being academic and dull, the newer BTEC or Design and Technology A-levels tackling real problems, and demanding personal involvement and commitment."

Out-dated content

Out-dated and poorly relevant content (GB. Sir Gareth's report)

PhD issues

Low stipends, Duration of the funding: 3 years is not enough, Inadequate training during the PhD programme (GB. Sir Gareth's report)

Post doc issues

Pay is lower than outside Academia, few opportunities to undertake training, Uncertain future since employment is not guaranteed after the end of the contract (GB. Sir Gareth's report)

7. TEACHER TRAINING, QUALIFICATIONS AND DEVELOPMENT

The issues outlined in the literature in this area relate to the teachers' initial and continuous training that may have an impact on teaching quality, but also on the motivational factors that certainly have an influence on the way students develop attitudes towards science studies.

It is frequently reported that teachers find that they lack resources and opportunities to reflect upon their way of teaching. The reasons would relate to the lack of opportunities that would take them out of their class to think and learn with more distance.

Moreover, in some countries, there are concerns about the fact it is more and more difficult to recruit teachers in S&T. However we have few supportive elements for this category of factors.

7.1. PRIMARY TEACHERS

7.1.1. S&T qualification

In many of the studied countries, most primary teachers come from a non-S&T background and many have not had any specific professional training on S&T.

This can translate into various consequences:

- Their being ill at ease with teaching S&T, they can avoid these subjects and devote less time than needed to teaching them,
- Pupils can feel that their teaches tend to avoid S&T subjects and this could have negative impact on their interest
- Teachers may lack adequate didactic skills to teach S&T
- Some teachers may lack the necessary S&T context knowledge needed to effectively teach science

- **Supportive elements**

TIMSS 2003: most of primary teachers do not have majors in Science

Sir Gareth's report[54]

In Flanders, according to the Inspectorate, teachers' content knowledge and pedagogical skills show deficits especially for Technological Education at both primary level and secondary level. For the other subjects (mathematics and sciences) there are also some deficits. (Euroscene report for Flanders);

Enrolment trends in school science education in Australia. Dekker & De Laeter [55]

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[54] "particularly in science there are also concerns over the level of initial training that teachers receive"

[55] "Most primary school teachers lacked confidence and competence to teach a comprehensive science programme, largely because their pre-service education did not include an in-depth treatment of science, and the

A commitment to America's Future: responding to the crisis in mathematics & Science Education[56]

7.1.2. Confidence to teach science

Some studies show that primary teachers may lack confidence in S&T subjects and that this can impair their ability to teach them

The most obvious way to act on educational challenges is through teachers. Many approaches have been tried like communicating to them very detailed frameworks for teaching, detailed curricula and ready-to-use methods. These tools are not always looked at as helping, but rather as a sign from the institution, that teachers are not considered professionals.

- **Supportive elements**

TIMSS 2003: 4th grade teachers felt generally less well-prepared than 8th grade teachers

Harlen, W: "Primary Teachers' Understanding in Science and its impact in the Classroom" (UK/Scotland): "what emerged was a series of strategies that teachers used to cope with low confidence in their ability to teach science. These included:

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"

Osborne papers (GB) [57]

7.1.3. The nature of the key knowledge they need

- **Deep understanding rather than knowing a lot**

Harlen, W - "**primary Teachers' Understanding in Science and its impact in the Classroom"** (UK/Scotland): " The findings of this and other research (…) leaves little room for doubt that

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majority of students embarking on a career in primary teaching entered university having studied little science in senior secondary school" (about the situation in 1997).

[56] "at present, too many young people learn mathematics from teachers who lack basic knowledge of the field. One in three high school students is taught mathematics by a teacher who lacks a major in mathematics, mathematics education or a related field (for example, engineering). In middle school, 61% of students are taught mathematics by teachers who do not have a major or minor in mathematics, mathematics education or a related field.

- [57] "Teacher 'read' from the increasing plethora of national curricula, prescribed scheme of work, or prescribed text-books that their professional judgement is not to be trusted". "And just as the removal of the opportunity for personal autonomy is resented by pupils, so it is likewise by teachers who become similarly alienated and disengaged."

increasing teachers' own understanding is a key factor in improving the quality of teaching and learning science.

At the same time it must be borne in mind that the reason why understanding is needed is not so that teachers can convey factual information didactically to pupils. Rather it is so that they can ask questions that lead children to reveal and reflect on their ideas, so that they can avoid 'blind alleys", so that they can provide relevant sources of information and other resources, so that they can identify progress and the next steps that will take it further. These things cannot be done if teachers don't understand the ideas they are aiming for.

Hopefully this recognition of the subtle role of teachers' own knowledge will deter a panic response to try to fill primary teachers with dozens of facts when what they need are the big ideas, the broad understanding that will enable them to guide children's learning. The aim cannot be to enable teachers to know the answers to all the questions children may ask. This would not only be impossible, given the creative curiosity of young children, but often inadvisable when children would not understand the answer. What teachers need to have at their finger tips are strategies for handling children's questions and turning them to the advantage of investigative learning. They also need sources of information and a level of general understanding that facilitates quick and effective use of these sources. Again, this points to understanding of broad principles, the big ideas, that enables use of their professional skills."

7.2. SECONDARY TEACHERS

7.2.1. Updated knowledge

- **Findings**

S&T are fast-evolving subjects and in many countries the secondary teachers' average age is high. Continuous training is often lacking or does not focus on theoretical subject content. As a result, many S&T teachers may need 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.

Moreover he formal level of education of secondary teachers is weak in some countries such as the US

- **Supportive elements**

Insufficient continuous training opportunities is reported in some countries. This lack relates both to the science content and to the pedagogical skills/didactics.

OECD STI Outlook 2004: 56% of those studying physical sciences in secondary education and 27% of those studying mathematics are educated by teachers that don't have any formal qualification in these subjects.

7.2.2. Financial and social status,

- **Findings**

In some countries, teachers may feel dissatisfied with their financial and social status.

This can impair their motivation level and thus have a negative impact on both students' acquisition of knowledge and students' propensity to choose S&T studies.

- **Supportive elements**

Teachers Matter: attracting, developing and retaining effective teachers provide data on teacher salary trends, salary competitiveness of other profession, and salary system of teachers. The difficulty many countries face in attracting able people into SMT teaching is likely to be associated with the decline of the overall attractiveness of the teaching profession relative to other professions. For example, there is evidence that teachers' salaries have declined relative to those other occupations. It is also likely that salary scale of teaching profession is often unique and it is difficult to provide additional reward for SMT subject teachers.

7.2.3. Number

- **Findings**

Some countries experience difficulties in recruiting S&T teachers and as a repercussion, this may have a negative influence on the quality and the motivation of the recruited teachers. (When school systems face teacher shortage, they usually tackle this problem by increasing class size, recruiting unqualified teachers or increasing teacher workloads.)
Moreover, retention rates are lower for science and mathematics teachers

- **Supportive elements**

Teachers Matter: attracting, developing and retaining effective teachers

Talking about leaving, Seymour, E. and Hewitt, N.M.[58], [59]

Sir Gareth's report[60]

- **Comments**

Including Flanders, some OECD countries do not have any teacher supply problem, and in fact some countries are facing oversupply of teachers. This issue is largely country specific.

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[58] "…the consistent discovery, campus by campus, that science and mathematics teaching is devalued as a career for SME baccalaureates, and that students with a strong interest in teaching science and mathematics are effectively discouraged from pursuing this career path."

[59] **Talking about leaving** - Seymour, E. & Hewitt, N. - USA - 1997 : "teaching was consistently portrayed as an "alternative or "deviant" career, which a handful of switchers and non-switchers pursued despite the disapproval of faculty, family and peers". "We commonly heard that more people would follow their inclination to teach were the pay or prestige of the profession better, or were it less time-consuming and expensive to undertake an education qualification on top of a baccalaureate degree." "students also saw teaching as a form of professional activity that was undervalued by the wider community. It seemed to pay poorly compared with other options, and family and peers tried to dissuade them from choosing to teach" "There was no doubt in the minds of that fifth of our overall sample who had considered teaching as a career that their ambition was regarded as deviant by most of the significant people in their lives"

[60] "shortage in the supply of physical science and mathematics teachers / lecturers" "more attractive and better paid opportunities open to them"

7.2.4. Giving career advice

- **Findings**

Many secondary education S&T teachers do not allow themselves to counsel their students about their future study paths and careers. They say they lack information and contacts with S&T professionals and have only a partial knowledge of the careers open to young S&T professionals.

- **Supportive elements**

"On the whole, science teachers did not feel able to keep up with careers & employment in S&T: there was a "career person" to do this. The teachers were worried about giving incorrect information." Choosing science at 16

7.3. TERTIARY TEACHERS

7.3.1. Didactic skills

- **Findings:**

S&T teaching staff is often recruited among high-level researchers and on the basis of their high-level competences in their specific subject. In many countries, this does not include any requirement for didactic/teaching skills nor any further training in this kind of skills.

- **Supportive elements**

Talking about leaving, Seymour, E. and Hewitt, N.M.[61]

7.3.2. Financial status

- **Findings**

In some countries, the package offered to S&T tertiary education teachers is not attractive enough compared with other opportunities on the work-market which may result in under motivation and difficulties in recruiting.

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[61] "We have also found the level of contact between SME faculty and the Science and Mathematics specialists in Colleges of Education on the same campuses to be low or non-existent. The lack of such a dialogue inhibits discussion of ways to promote science and mathematics teaching as a career, or to ease the path to professional certification for SME majors who would like to teach."

7.3.3. Relative importance of teaching in their careers

- **Findings**

In many countries, tertiary education teachers do not only teach but are involved in research, consulting and management activities.

Also, in some cases, teaching can be considered as of not primary importance for them, especially in countries in which their assessment and career path rely more on research activities

- **Supportive elements**

Talking about leaving, Seymour, E. and Hewitt, N.M

"students frequently made invidious (i.e.difficult) comparisons between the enthusiasm and good pedagogy of their former high school teachers, and what they viewed as the poor skills of many college faculty and their failure to inspire students interest. They quickly learned that teaching was viewed as an inferior form of professional activity by SME faculty, though not necessarily by faculty in other disciplines."

8. GENDER AND MINORITIES

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.

8.1. INTRODUCTORY ELEMENTS

8.1.1. Gender

Women are strongly under-represented S&T studies and careers. They would be the more evident source to increase the number of people undertaking S&T studies.

- But these issues are difficult to act upon as a number of complex factors are involved including social, and economic ones.
- For what concerns education, some experts are working on the re-engineering of the education process to offer equal opportunity to both genders[62]. But for the moment, it does not seem that a consensus has been established on this point.

The facts are that in many countries, beginning as early as elementary school, boys have more interest in studying science than girls.

[62] See for instance the Swedish initiatives described in « recruiting female students in higher education in mathematics, physics and technology »

This doesn't appear to be an ability-related issue as girls tend to succeed well in S&T, especially in these early stages

The different S&T subjects are not impacted equally as biology and life sciences attract far more female students than computer sciences, maths and physics.

The **leaky pipeline** (throughout secondary stage, university and professional life, the number of women in S&T decreases) and the **glass ceiling** (the number of women in the most selective S&T fields is extremely small) are two phenomena affecting female students.

- **Supportive elements**

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."[63]. In most countries females feel more anxious in maths.[64] The analysis shows that students who are less anxious perform better regardless of other characteristics [65]

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[66]

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

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[63] 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"

[64] 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

[65] 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

[66] "Beginning as early as elementary school, boys have typically possessed more interest in studying science than girls (Clarke, 1972; Clark & 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 memorize", and "boring" (Kahle& Lakes, 1983). By middle school, girls attitudes toward science tend to decline and this decline may persist through high school (Sullins, Hernandez, Fuller, & 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."

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.

SAS: results relating to interest show a strong gender-effect

8.1.2. Minorities

What constitutes a “minority” is obviously subject to many variations from one country to another. However, in many countries, there is a concern about the low rate of pursuit of S&T studies among some groups of people, whose common characteristics are specificities in their cultural background. Some minority groups succeed very well in MST, like the Asian minority in the US, while others are characterised both by a low MST intake rate and high drop out rates.

Often, the analysis for minorities’ attitudes and success rate is complex. One reason is that in some countries, as it is the case for France, such characteristics are not tracked. It would be negatively perceived to identify people according, for instance, to their ethnic origins. Another reason is that often, those minorities cumulate the disadvantages resulting from belonging to socio-economically less-privileged background with the effect of belonging to a minority group. Then it is difficult to distinguish between the factors linked to the economic background from the ones coming from the cultural background.

8.2. SHARED ELEMENTS

8.2.1. A need for Role models

- **Findings**

Many studies show that the existence of a role model is of primary importance in the choice of S&T studies. This importance of role model appears to be all the more significant for female students and students from some minorities.

The person that embodies this function may be a family member, a teacher or less frequently another familiar adult.

This influence is considered as having a stronger impact in science than in other fields. This is probably because female/minority students feel more difficulties in projecting themselves onto S&T careers than in other fields.

- **Supportive elements:**

Gender differences in students’ experiences, interest and attitudes toward science and scientists

Baker and Leary (1995): In-depth interviews with girls in grades 2, 5, 8, and 11 to determine what influences girls to choose science. Specifically, girls that chose science careers indicated that they were drawn to them because of strong affective experiences with a loved one such as a parent or grandparent

Existence of Role Models is shown as being of high importance by Marie Duru-Bellat and Durant-Delvigne (1988). Having female science teachers would have a significant impact on course choice.

Les maths & les sciences n'ont-elles plus la cote? :p101: Women are generally reticent towards S&T fields because they are not familiar with them, notably because they lack female role models.

Talking about leaving: issues of race and ethnicity

Brown, 1994

Thomas, Clewell & Pearson, 1992

8.2.2. External expectations

- **Findings**

Signals female/minority young people get about their performance and what they can expect to achieve make the choice of S&T studies difficult. These signals may come from a large range of sources: Society at large, peer groups, parents, teachers and advisers.

As part of the society, teachers and career advisors may have some stereotypes about female/minority students.

- **Supportive elements**

Talking about leaving: issues of race and ethnicity: "As with the under-representation of women, the beliefs of high school teachers and counsellors and college faculty about the reasons for minority under-representation in the science may, in themselves, be regarded as contributing to the problem".

A survey by Treisman in 1992 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.

Hilton, Hsia, Solorzano and Benton, 1989 and Clewell, Anderson and Thorpe, 1992 have suggested that students coming from minority background may not realize that academic preparation and planning for careers based on the sciences need to begin as early as junior high school.

8.2.3. Peer groups

- **Findings**

The small number of minority/female students in MST, and the cultural distance with non-minority/male students keep them from constituting peer groups.

This situation may create a feeling of ethnic/cultural isolation with many negative consequences.

- **Supportive elements**

Talking about leaving: issues of race and ethnicity

Brown, 1994

Thomas, Clewell & Pearson, 1992

Pearson (Science, 1992)[67]

8.3. SPECIFIC ELEMENTS :

8.3.1. Gender

8.3.1.1.The genesis of gender difference in attitude towards science studies

- **Family wishes and expectancies**

Parents' wishes and expectancies are lower for girls, especially in S&T.

When a boy fails in S&T, parents tend to choose to have him repeat the year but keep on in S&T, while for a girl the choice is more often to change subject.

It is generally the father who impacts his daughter's attitude to S&T by encouraging and approving her interest for these questions. (Engler & Faulstich-Wieland, 1995, quoted in Les maths & les sciences n'ont-elles plus la cote?) [68]

Supportive elements :

Marie Duru-Bellat: L'école des filles

Mateo Alaluf & al : Les filles face aux études scientifiques

Les maths & les sciences n'ont-elles plus la cote ?: parents expectations are lower for girls in S&T

Talking about leaving - Seymour, E. & Hewitt, N. - USA - 1997
"We have consistently observed that women find it easier to give themselves permission to reject a conventional, materially-focused career path in favor of an 'alternative' career based on intrinsic interest, self-development, altruism, or the need for social interaction.(…) However, here it is important to reflect that one reason why SME majors seem to be less attractive to women and to many students of color, is that they are seen as offering an insufficiently congenial (or worthwhile) career or lifestyle."

- **Out of school activities**

[67] Talking about leaving: "As Pearson observes (Science, 1992), because they are forced "to learn in isolation", students of colour do not have the same educational experience as white male peers. Black women, in particular, complain they are often the only minority students (and are often the only woman) in their SME classes (Brown, 1994)."

[68] Cockburn (1988) explique le peu d'influence qu'exercent les mères à cet égard par une sorte de cloisonnement entre invention, développement, entretien et réparation des dispositifs et appareils techniques d'une part, leur utilisation et leur maniement d'autre part. Les hommes sont plutôt familiers du premier domaine, les femmes du second; et lorsqu'on parle technique, c'est surtout le premier domaine qui est concerné.

Girls appear to have very different out of school experiences in science than their male peers and these are very less frequently oriented towards science.

Significantly more boys than girls indicate that they had visited a factory, a weather station or an electric plant. More boys than girls indicate that they read science articles, watched science television shows, and completed science projects.

Out of school science orientated activities are known to play a significant part in developing young people's interest towards science.

Supportive elements

Gender differences in students' experiences, interest and attitudes toward science and scientists[69]

Osborne Attitudes towards science :
"More importantly, Kahle argues that her data show conclusively that 'lack of experiences in science leads to a lack of understanding of science and contributes to negative attitudes to science' (emphasis added)." (…)
"The predominant thesis offered to explain this finding is that it is a consequence of cultural socialization that offers girls considerably less opportunity to tinker with technological devices and use common measuring instruments (Johnson, 1987; Kahle and Lakes 1983; Smail and Kelly 1984; Thomas 1986)."

- **School interactions**

Teachers, as part of society, respond to mainly the same stereotypes as in the general population. Then, their evaluation of students' performances differs strongly between boys and girls. When a boy's achievement is attributed to ability and skills, girls' achievement tends to be seen as the result of hard work and perseverance.[70]

Some studies have shown that in some maths contexts, teachers tend to devote more time and individual attention to boys.[71]

Several studies have shown that girls tend to comply with the gender stereotypes more strongly in presence of boys. [72]

This led to several experiences of S&T classes for women only. In the secondary stage, for example, when taught separately, girls seem to be more prone to make choices against stereotypes and express interest in physics or technology [73]

The causes for this pattern are multiple:

- Physics and maths being considered as masculine, girls would choose against these subjects in order to be considered as feminine by their male colleagues [74]

[69] "Kahle and Lakes (1983) were among the first to show that girls reported having very different out of school experiences in science than their male peers. Significantly more boys than girls indicated that they had visited a factory, a weather station or an electric plant. More boys than girls indicated that they read science articles, watched science television shows, and completed science projects"(…) "During the interviews, girls with positive attitudes toward science attributed their attitudes, in part, to extracurricular experiences such as doing science at home, reading about science, or watching science-related television shows"

[70] Mireille Desplats 1989; Nicole Mosconi, 1999

[71] Desplats, 1989

[72] lorenzi-Cioldi, 1988; Durand-Delvigne & Duru-bellat, 1998

[73] Lawrie 1992, Solnick 1995

[74] Kelly, 1985

- Teachers often use to split up their group in “boys” and “girls” and use this artificial opposition as a pedagogical tool. This could lead to artificially emphasize 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 impact on students’ self-confidence[75].

- The gender stereotyped image of discipline would be reinforced by school textbooks [76]

Teachers would lack the specific skills & knowledge on the way to teach S&T to girls

- **Supportive elements:**

Gender differences in students’ experiences, interest and attitudes toward science and scientists [77]

Crabbé & al., 1985; Rignault & Richer, 1997 Kimball, 1989; Crossman, 1987

Kelly, 1985 Lawrie 1992, Solnick 1995 lorenzi-Cioldi, 1988; Durand-Delvigne & Duru-bellat, 1998 Mireille Desplats 1989; Nicole Mosconi, 1999 Desplats, 1989

Les maths & les sciences n’ont-elles plus la cote ?: teachers have lower exectations for girls in MST and their behaviour tend to disadvantage them

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

- **Socialization**

Some studies suggest that pupils’ interactions differ significantly depending on whether the context is coeducational or unisex.

The unisex 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.

- **Supportive elements:**

Lawrie & Brown 1992

- **Orientation**

Teachers and counsellors patterns: 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.

Under-evaluation by girls themselves: Girls tend to under-evaluate their performances in maths and S&T. This leads them to avoid these subjects as they fear not being able to succeed

[75] Kimball, 1989; Crossman, 1987

[76] Crabbé & al., 1985; Rignault & Richer, 1997

[77] “Even within the same science classrooms, studies have shown that male and female students often have very different experiences. Jones and Wheatley (1989, 1990) found that males had more opportunities to conduct experiments, carry out demonstrations, and manipulate equipment.”

Seeking for a job that participates in helping people: Among the criteria that lead girls to the choice for their career, helping people is a strong positive one.

- **Supportive elements:**

Experiment conducted by B. Dumora 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.[78]

Vanheerswynghels, 1994, 1996: In case of academic difficulties, family tend to chose more easily to reorient girls to easier sections while for boys, they will choose to maintain them in the strongest sections, even if the cost for that is repeating the year.

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

Gender differences in students' experiences, interest and attitudes toward science and scientists:
Baker and Leary found that the girls in their sample rejected physical sciences because these areas were not viewed as helping or caring, instead preferring areas such as biology that would allow them to help people, animals, or the Earth.

Newtonia : When asked about their criteria for selecting a career, Belgian students' answers differed depending on the sex. Girls were more likely to answer they used the criteria of the social utility of the career, whereas men were more likely to mention the opportunities in the job market and the level of income

Germany - Zwick/Renn 2000: deeply rooted patterns of gender specific interests lead to gender specific recommendations regarding the choice of study subjects

- **Lack of confidence**

Girls tend to undervalue their attainments.

Various studies show that self appreciation by girls is less positive than boys.

- **Supportive elements:**

Eccles & Blumenfeld, 1985; Eccles & Jacobs, 1986

Marsh, 1989; Bandura, 1997: In traditionally masculine subjects, girls tend to undervalue their abilities

Also, when girls succeed in maths, they tend to attribute this success to their hard working, while attributing boys' success to natural ability. (Kimball, 1989; Ecles & Jacobs, 1986).

8.3.1.2.A male culture

A male culture in engineering and science (mainly computing and physics) put women off these subjects. MST are generally perceived as male subjects and male stereotypes are associated with them.

Since the S&T subjects are traditionally male, the teaching of them has been developed in a context

[78] Quoted by Françoise Vouillot, at the Symposium "Où sont les filles?"

that is more favourable to men. Some male values may be promoted through the way S&T is taught, which can push female students away.

- **Supportive elements:**

(1) At school and high school

Computer class for female only – Nortel

Les maths & les sciences n'ont-elles plus la cote?

(2) At university

At university, the higher the proportion of courses attended being taught by women, the higher the rate of female students persisting in studying sciences. This phenomenon is untrue for non S&T subjects. (Robst, Keil & Russo, 1998, US)

"The epistemological underpinnings of the teaching methods used within many science programmes have been criticized from a gender perspective on the grounds that such methods tend to disregard the social nature of knowledge formation (Burton, 1995; Hawkesworth, 1996)." [79]

Germany - Minks 2000: A male culture in engineering and science (mainly computing and physics) put women off this subjects. Women are often less committed to engineering studies: They give up earlier when they are disappointed from the study conditions or when they feel that their expectations are not met.

8.3.1.3. A differently focused interest?

In surveys, female young persons tend to show a stronger interest in people than in facts. This is both true when asked about their studies choices and about professional choices.

They perceive science as oriented to facts and things human issues.

8.3.1.4.A rational choice?

- **<u>Chance of success in the studies</u>**

Two kinds of context: countries with affirmative action policy and countries without.

In countries without such a policy, young women may anticipate a lower probability of success than their male peers and then refrain from taking S&T studies.

- **Supportive elements**

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 & Agnes Wold in a 1997 study for Sweden (quoted in Les filles face aux études scientifiques, p20)

- **Comments**

[79] Recruiting Female Students to Higher Education in Mathematics, Physics and technology, p10

More data needed in particular about the real rates of success

Data needed: wages differences, unemployment rates…

- **<u>Seeking for a satisfying life equilibrium</u>**

- **Supportive elements**

Studies show that female university students tend to consider that S&T careers are not very compatible with family life (Ware & 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. (Thomas Couppié, Dominique Epiphane & Christine Fournier; 2001)

Les maths & les sciences n'ont-elles plus la cote?: the professional context makes young women believe, whether it is true or not, that they will not be able to balance professional life and family life (p11)[80]

8.3.2. Minorities

8.3.2.1.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.

8.3.2.2.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 / positive discrimination is in use. Even in the absence of any affirmative action policy, the geographic 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).

- **Supportive elements**

Talking about leaving: issues of race and ethnicity[81]

[80] Comme les femmes incluent dans le choix de leur métier le critère de la compatibilité entre vie professionnelle et famille, il y a également lieu de penser que les informations dont elles disposent – ou des suppositions – les portent à considérer la conciliation entre sphères professionnelle et privée comme un sérieux problème dans ces domaines. (…) médecine mise à part, les professions comportant un faible taux d'emplois à temps partiel sont également celles où les femmes sont relativement rares. (…)Dans la mesure où femmes et hommes n'accordent pas la même importance à la possibilité d'obtenir un emploi à temps partiel, on pourrait y voir un critère de plus dans le choix des études.

8.3.2.3.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.

- **Supportive elements**

Osborne J. Attitudes towards science : "Another factor that seems to be a significant determinant of attitude towards school science is the attitude of peers and friends (Breakwell and Beardsell 1992; Talton and Simpson 1985).

8.3.2.4. Aversion for risk

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.

- **Supportive elements**

Economics of education

8.3.2.5.Insufficient financial resources

Insufficient financial resources to complete an SME degree have 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, exacerbates their financial problems. The long hours spent in paid jobs reduce their ability to fulfil the academic requirements.

- **Supportive elements**

Talking about leaving: issues of race and ethnicity

Rotberg 1990

Rodriguez, 1993

Mortenson 1995

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[81] "Under-Prepared and Over-Confident : Many of the students of color that we interviewed came from predominantly minority high schools where they had been outstanding students. However, those who had excelled in sub-standard or even average high schools faced an uphill battle in the competitive culture of the university. They were shocked to discover that they had over-estimated their capabilities. Because they had been led to believe that their knowledge and skills were greater than they actually were and had been treated as special by their high school teachers, these students were doubly at risk: they entered SME classes both under-prepared and over-confident in their ability to undertake them."

PART FOUR: POSSIBLE REMEDIES

1. METHOD

A number of countries have initiated or are initiating action plans and other types of remedies to fight the S&T enrolment decline.

Examples of these remedies have been chosen by the experts of the working group as significant and valuable in their national context.

They are of two types: the “action plans” that include a large spectrum of actions at a large level (nation or state) and the “promising practices” that are more specific actions focused on a reduced number of specific objectives and targets.

Criterion have been established for the selection of the remedies .

Particularly:

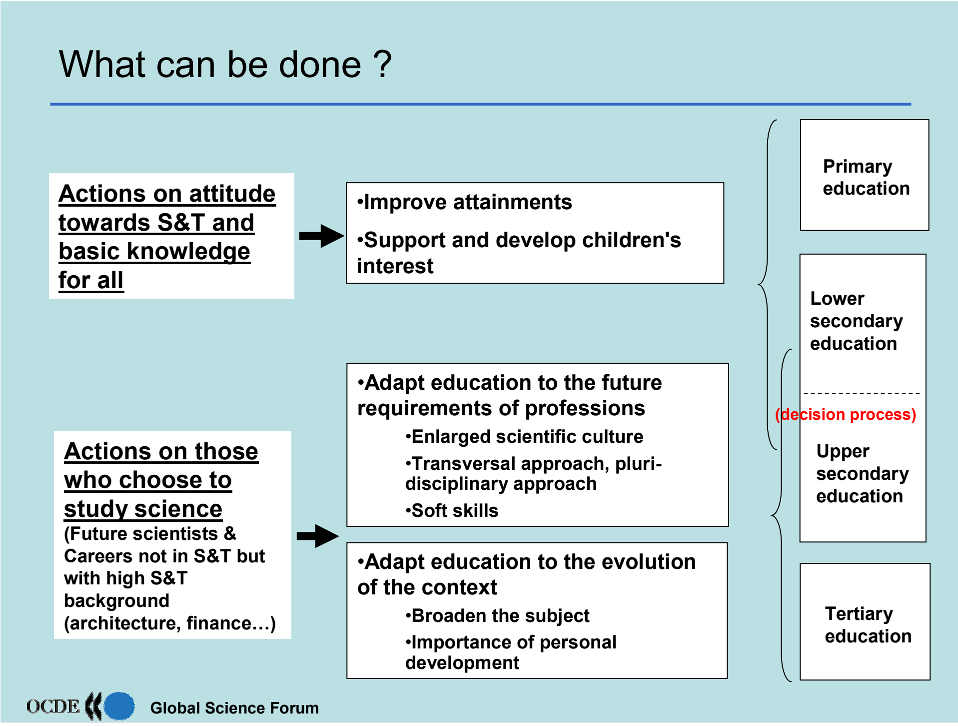
- their scope and possibility to implement them at a large scale
- their results (validated by an evaluation process)
- their cost-effectiveness

Some of the remedies presented here may not comply with all of these criteria but have been nevertheless selected for their interest.

More details about the examples of remedies are given in the annexe.

However, very few of all these initiatives have been properly evaluated in terms of their impact on student enrolment in S&T subjects. In addition, many initiatives focus on a limited number of children and would be difficult to scale up.

2. SUMMARY OF MAIN FINDINGS FROM THE ANALYSIS



2.1. LEVERS WITH IMPACT ON S&T TASTE AND LITTERACY FOR ALL

Hereafter are a selection of remedies aimed at increasing S&T taste and Litteracy. These are directed towards all students, including both those who will choose to study science and those who will not.

2.1.1. Start young !

Interest in S&T appears during primary school, and longitudinal surveys show that this interest remains stable between the ages of 11 and 15. Such interest may have a strong influence on subject choices, but long-term impact of measures at this age are difficult to evaluate. Interesting measures target the teachers themselves (confidence and taste for S&T), teaching content (hands on experience), and the pupils (extracurricular activities, communication…).

2.1.2. Give priority to curiosity and interest over raw facts and knowledge

The aim of the curriculum at early stages should be to raise curiosity pleasure and interest, and to give self-confidence regarding S&T.

The priority should be given to deep understanding and methods over raw facts and knowledge.

2.1.3. Develop specific teaching methods

Practical experiments and hands-on help raising interest. A balance should be found with theoretical lectures.

Cooperative learning have two significant positive output: developing soft/professional skills and being more attractive than other methods to female students

2.1.4. Provide opportunities for identification (Role models) for female students and students with minority background

Identification seems to be the key word: provide a large range of opportunities to meet female/minority S&T teachers and professionals whom young people may identify with.

2.1.5. Work on primary Teachers self confidence and taste for teaching S&T

Teachers' self-confidence is a key factor in S&T teaching at primary level.

Teachers' S&T knowledge, continually updated is crucial at later stages

2.1.6. Link what is taught to the Society

Opportunities should be given to children to have better knowledge of S&T impact on society. For technology, a distinction should be drawn between technology as a tool (what is rather familiar to many children) and technology as a creation process to elaborate new goods/devices and respond to a need.

2.2. LEVERS WITH IMPACT ON FUTURE S&T-BASED PROFESSIONALS

Hereafter is a selection of remedies specifically aimed at increasing the willingness of targeted young people to choose S&T studies.

2.2.1. Pay specific attention to the years around 15

This is the age at which interest towards S&T declines the most sharply, when gender differentiation starts to translate into choices, and a key period for future orientation. Specific actions can focus on meeting with real professionals, exposure to cutting-edge science and technology and their use in modern life, debates on the role and social relevance of S&T and all actions directed towards a "humanization" of science teaching.

2.2.2. Propose opportunities for students to come back into S&T track studies

Students have to make their first orientation choice usually at the age of 15-16. Those who, for various reasons, do not choose to follow S&T studies as their main subjects are often definitively excluded from these fields. Giving a second chance to 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.

2.2.3. Develop multi/trans-disciplinary courses and soft skills

Over-specialization and the lack of social knowledge are among the factors that can deter some groups of students from pursuing tertiary S&T studies. In addition, even for S&T careers, skills such as communication, project management or team work are increasingly valued. New programmes with an enlarged vision of S&T have shown to be more attractive to many students, especially girls.

Adaptation of the offer to new targets (women, students from average academic level, students from less-privileged groups, students from minority groups):

- Include in S&T subjects a significant quantity of general education (including economy, politics…)
- Promote broader subjects with contextualization and multi-disciplinarity
- Put a stronger emphasis on soft skills (communication, team working, planning, project management, languages…)
- Promote teaching methods that includes more interactions
- Design education paths that provides opportunity to enter the job market at various stages

2.2.4. Develop opportunities for contacts with S&T world

These contacts could remedy many factors at the same time: need for role models, better knowledge of careers and up-to-date science, interest and gratification (by meeting enthusiastic people)…

2.2.5. Communication on careers

Communicate on their diversity, the mobility they permit, their financial prospects.

2.2.6. Pay specific attention to the first year of tertiary education

The first year of science programmes often has the highest drop-out rate. Specific pedagogical effort could help reducing these losses.

3. WHAT RESEARCH CAN TELL US:

3.1. START YOUNG

Many researches show that the origin of interest towards S&T is to be found in early ages.

Self concept, which is the belief that someone holds of his/her own “value” in relation with a subject, build up also very early.

Some longitudinal studies followed the same group of children between two ages (generally between 11 and 15) to show the variation in their interest towards science. The results of these studies are that interest is very stable during this period.

Moreover, a 2004 study indicates that most scientists (61%) say they became interested in science before the age of eleven (Bayer).

Also, even in the cases when interest changes afterwards, the level of interest young people have during lower secondary education has a strong impact on subjects choices, that may limit the future possibility to choose science studies.

- **Supportive elements:**

Framing ‘choices’: a longitudinal study of occupational aspirations among 13-to-16-year-olds. Andy Furlong and Andy Biggart. [82]

Bayer facts 2004

Simpson & Oliver (1990): [83]

Alison Kelly, “when I grow up, I want to be….”: a longitudinal Study of the development of career preferences, 1989[84]

Axis Study “Bèta/techniek uit balans” (2000 – not available in english) concluded that the attitude towards science/technology is already formed when a child is in primary school.

Woolnough **- Factors affecting students’ choice of science and engineering**:
“For those who had made a decision towards, or away from, a career in science and engineering, many had done so before the end of year nine, age 14th. At the one extreme 38% of the future physicists had decided on a career in these fields by the age of 14, while at the other 42% of those who were to do badly at science and go on to the arts side had made the decision away from science and engineering by the age of 14. Only 22% of the engineers, and 22% of the able non scientists, had made up their mind by this time”

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82 “while males and females tend to aspire to very gender-specific occupations, ideas about the suitability of occupations are formed at a relatively early age and overall levels of change are quite small”(…)”if efforts to broaden the occupational horizons of young women are to be successful, intervention needs to be considered at an earlier stage than has traditionally been the case. In this context, our research highlights a need to begin careers education in the primary school.”

83 Conclusion from their longitudinal study: the way students feel towards science and their achievement in science at the tenth grade level is “a strong predictor of subsequent science achievement in high school”. Moreover they say “Science self concept at the tenth grade level is a good predictor of both number and type of science courses a student will take during high school.”

84 “This suggests that early ideas about careers can affect later decisions by limiting the range of possibilities to those for which the appropriate school subjects have been studied.

Framing 'choices': a longitudinal study of occupational aspirations among 13-to-16-year-olds, Furlong & Biggart: "while males and females tend to aspire to very gender-specific occupations, ideas about the suitability of occupations are formed at a relatively early age and overall levels of change are quite small"(…)"if efforts to broaden the occupational horizons of young women are to be successful, intervention needs to be considered at an earlier stage than has traditionally been the case. In this context, our research highlights a need to begin careers education in the primary school."

- **Example of practices:**

All remedies aimed at primary school students and teachers and those related to early out of school activities.

Obviously, the teaching of a minimum of S&T early at primary school

Specifically: French 2000 reform, partly based on the « La main à la pâte" results, introducing the teaching of S&T as a specific subjects at primary school.

Informal science activities aimed at the entire family.

3.2. PUT SPECIFIC ATTENTION TO THE YEARS AROUND 15

This is the time when interest towards science declines the more sharply, the time the gender differentiation starts to translate into decisions and the time the most significant and permanent decisions for future orientation take place.

- **Supportive elements:**

Framing choices: a longitudinal study of occupational aspirations among 13-16 year olds

Furlong, A., 1999

Alison Kelly, "when I grow up, I want to be….": a longitudinal Study of the development of career preferences, 1989

Osborne, J. Attitudes towards science:
"A clear feature of the research is the decline in attitudes towards science from age 11 onwards that is documented by a number of studies (Breakwell and Beardsell 1992; Brown 1976; Doherty and Dawe 1988; Hadden and Johnstone 1983; Harvey and Edwards 1980; Johnson 1987; Simpson and Oliver 1985; Smail and Kelly 1984; Yager and Penick 1986). These all show how children's interest and attitude to science declines from the point of entry to secondary school. (…)The picture is confused by measurements of attitude undertaken by the TIMSS survey (Beaton, Martin, Mullis, Gonzalez, Smith, and Kelley 1996). For instance, in England, 78% reported as liking science or liking science a lot. More than 80% of pupils reported liking integrated science in Iran (93%), Singapore (92%), Thailand (90%), Kuwait (89%) and Columbia (87%). These data would suggest that the decline in interest may not be linear, but may accelerate rapidly from 14 onwards. »

Woolnough - Factors affecting students' choice of science and engineering:

" Most decisions were made just before or just after GCSE. Of those who were to become engineers, 44% made de decision in the 6th form [i.e. between 16 and 18], after they had decided to continue with A-levels in the physical sciences."

"Various studies have shown that students' interests in science decline sharply during secondary schooling (Rosier and banks 1990, Baird and Penna 1992, Baird 1994) Quoted in "enrolment trends in school science education in Australia". Dekker& de Laeter (cause: quality of the science education provided and/or distracting influence of the transformations due to adolescence?)

Changing pupils' attitudes to careers in science - Woolnough Brian E

"Many start their secondary career by seeing jobs in science as being interesting, well paid and useful. They enjoy their school science, especially the practical work. Five years later, many – especially many girls – have lost that enthusiasm, that enjoyment (that innocence?), and their belief that they would find a scientific career interesting and possible"

- **Example of practices**

All actions oriented towards these targets

Specifically: non co-educational classes, meeting with real professionals, exposure to cutting-edge science, debates on the utility and social relevance of science, all actions directed towards "humanization" of science teaching.

3.3. DESIGN DIFFERENT POLICIES FOR THE DIFFERENT GROUPS OF STUDENTS

Interest towards S&T studies may take ground on different characteristics. In depth studies with interviews show that what attracts some young people may be exactly what deters some others.

This is, for example, the case with the level of difficulty with some being excited by challenge while some others prefer more gradual approach.

Another significant example is the status of competition versus cooperative learning.

Solutions taken to adapt teaching to the needs of a specific group would deter another group. Thus, the diversification of practices and of possible studies paths is essential.

This differentiation must take place at any level of education, even the earliest.

- **Supportive elements:**

Woolnough "Changing pupils attitudes to careers in science - The author points out that a single kind of policy cannot address the motivational needs of the different kinds of students. A **specific attention must then be put to "handle diversity"**. *" We often seek to find the one most effective teaching strategy to motivate all students. But there is no such single way. Different people are most strongly motivated by different things. This statement, almost self-evident when we reflect upon it in the light of real students that we teach, has enormous and fundamental importance in the way we deal with young people. What motivates one pupil towards science will have the opposite effect on another. Some pupils will be motivated by intellectual challenges in science, others will find such aspects impersonal and irrelevant. Some will find the practical work stimulating, others will find it unnecessarily dull. Some like the security of formal, structured teaching, others prefer the more high-risk approach of open-ended projects. Some will be more motivated by elegant abstractions. Some will want to work with people, some will want to work with artefacts or ideas. This diversity will be a central theme in the analysis of those factors which motivates pupils towards a career in science."*

"*It was interesting to note that those who expressed an opinion about the salary and the status of jobs in science did so in very positive terms. For most students aged 11-16, jobs in science are seen as well* *paid, secure and of good standing in the community. The oft-quoted view that jobs in science are seen as having low pay and low status has been derived from previous surveys of atypical, selective groups of very able (sixth form) students who are able to consider alternatives in careers as law, medicine and accountancy – careers outside the imagination of the majority of young people"*

3.4. FOCUS ON QUESTIONS, NOT ON ANSWERS

Stimulating curiosity and skills for lifelong learning would be more productive than forcing the largest amount of knowledge in students head.

3.5. OUT OF SCHOOL ACTIVITIES

Many actions taken to promote science learning relate to out of school activities.

Nevertheless the research results we found on their impact were contradictory.

- **Supportive elements:**

Osborne J. Attitudes towards science : "However, her findings are somewhat of a contradiction to those of Woolnough (1994) in that **she found no correlation between attitudes toward science and involvement in extra-curricular activities**, whereas **Woolnough found that involvement in these was a significant factor in choosing to study science post-16**. Further evidence for the value of science clubs is provided by Kingsland (1991). However, these findings are not necessarily in disagreement as Breakwell was studying 11–16 year olds (n = 1800), while Woolnough's study was with post-16 children who had passed the point of choice and where the value of such activities might be more consciously recognized."

- **Examples of practices:**

Science Summer camps
Science Centres & museums
Competitions

3.6. TRAIN THE PRIMARY TEACHERS:

Improve teachers' S&T content knowledge and didactic skills but also their **self-confidence** and **taste** for teaching S&T

- **Supportive elements:**

Primary teachers' understanding in Science and its impact in the classroom, Harlen W.

Effects of teachers mathematical knowledge for teaching on students achievement, Heather C. Hill, Brian Rowan & Deborah Loewenberg Ball (2004): They find a positive effect of teachers mathematical knowledge on students achievement, even at earlier stages of primary education.

- **Example of practices:**

Reforms of the initial qualification requirements

ex:: the Teacher Curriculum promoted by LUMA: improve teachers skills by upgrading the S&T requirements for entry into teacher training.

Innovation:

Ex: La main à la pâte provide teachers with new methods and pedagogical tools

3.7. PROMOTE A VISION OF SCIENCE AS SOCIALLY CONSTRUCTED:

If participation of historically marginalised and diverse learners is an aim, school science should be reframed in a way that promotes a vision of science as socially constructed.

Historical, social, political background should be given to the discoveries and knowledge construction

- **Supportive elements:**

Barton, 1998 [85]

"Talking about leaving" Seymour E.

"What makes Science Hard?" Tobias

- **Impact on:**

Image S&T/S&T professionals

Image of S&T careers

Pleasure/interest building

3.8. PUT EMPHASIS ON PROFESSIONAL/'SOFT SKILLS' BUILDING

- **Findings:**

[85] She argues that teachers need to actively and continually deconstruct the master narratives of science, and of teaching, learning and curriculum so as to convey democratic depictions of science that are more authentic and more inclusive. (quoted in "The role of research in reconceptualising science education for the 21st century", Carter & Smith)

In their actual professions, young scientists will need professional skills such as communication, project management, teamwork….

Very early in their career, their function may move them away from science ground work and towards management responsibilities.

The fact that very often subjects like maths, physics and chemistry do not include these skills is likely to be one of the reasons preventing young people from choosing these disciplines.

Promoting more comprehensive science studies that would correspond better to the actual needs of the work-market is a key remedy.

Moreover, female students are generally particularly interested in developing these professional skills

- **Supportive elements:**

The alumni survey conducted at Radboud university shows the mismatch between what alumni have learned at university and what they actually need in their jobs and the emphasis to be given to soft skills in S&T education.

Recruiting Female Students to Higher Education in Mathematics, Physics and technology - Wistedt, I.

« Higher education is supposed to provide society with well- educated scientists. But the demands of society are rapidly changing. In the public debate it has been proposed that future mathematicians, scientists and technicians need a much broader education than is currently offered within universities and university colleges. Skills in handling complex problems of an interdisciplinary nature, competence in co-operating with others and in presenting scientific knowledge orally or in writing are qualities which are highly appreciated in the labour market but less highly valued within the current educational practices of mathematics, science and technology. Since female students are believed to have substantial experience in developing such skills it is possible to view female applicants to science programmes as a resource, bringing new competence to formerly male-dominated subject areas. »

- **Example of practices:**

The initiative conducted in Sweden aiming at recruiting more women in S&T tertiary education (see Recruiting **female students to HE in mathematics, physics and technology -** An evaluation of a Swedish initiative). This initiative included pedagogical ideas such as "*the notion of the social character of learning (emphasis on social interactions & collective work forms, emphasis on dialogue as a strategy for surmounting single-subject perspectives & integration of knowledge from different subject areas; praxis oriented perspectives versus research oriented"*

3.9. INCLUDE A SIGNIFICANT AMOUNT OF GENERAL EDUCATION IN S&T PROGRAMMES

- **Findings:**

Including a significant amount of general education, including languages, politics & economy, in S&T tertiary education would contribute to fighting the image of S&T as narrow subjects and scientists as "out of society" persons.

- **Supportive elements:**

Osborne Attitudes towards Science:
“Tobias (1990), too, found that students did not choose science because they had a fear of cheating themselves of a ‘well-rounded liberal education’. Such findings are further reinforced by the work of Munro and Elsom (2000), which found that the compulsory nature of school science made less demand on science teachers to market their subject and, when they did, they predominantly emphasized its instrumental value rather than any cultural significance. Their findings would suggest that science teachers, and many of their students, still share Matthew Arnold’s nineteenth-century view that scientific training is a form of education that would produce only a ‘useful specialist’ and not a truly educated man (sic). In short, that a knowledge of science has no intrinsic cultural value as knowledge, which is an essential component for the educated woman or man. ”

3.10. DEVELOP LARGE SPECTRUM, MULTI/TRANS-DISCIPLINARY SUBJECTS

- **Findings:**

Specialization and the lack of social knowledge are among the factors deterring the ‘new’ groups of students (women, less privileged). New programs with enlarged vision on S&T may be a way to attract these targets

- **Supportive elements:**

Recruiting Female Students to Higher Education in Mathematics, Physics and technology - Wistedt, I.

« Higher education is supposed to provide society with well- educated scientists. But the demands of society are rapidly changing. In the public debate it has been proposed that future mathematicians, scientists and technicians need a much broader education than is currently offered within universities and university colleges. Skills in handling complex problems of an interdisciplinary nature, competence in co-operating with others and in presenting scientific knowledge orally or in writing are qualities which are highly appreciated in the labour market but less highly valued within the current educational practices of mathematics, science and technology. Since female students are believed to have substantial experience in developing such skills it is possible to view female applicants to science programmes as a resource, bringing new competence to formerly male-dominated subject areas. »

Osborne Attitudes towards science:
One of the major aims of balanced science courses, such as those implemented in the UK, was to remove gender bias in subject choice at age 14. Data published by Elwood and Comber (1995) shows not only that this aim has been achieved with more females entering for science GCSE (50.2% girls, 49.8% boys) despite making up only 49% of the 1994 cohort, but that more are achieving A*–C grades (45.5% girls, 45.3% boys). Moreover, the percentage of female applicants for undergraduate degrees in a range of subjects has increased significantly

- **Example of practices:**

Discipline-oriented approach / alternative science subjects (General sciences, marine sciences, environmental sciences science for life, sport sciences…)

3.11. PUT MORE EMPHASIS ON THE LATEST S&T DEVELOPMENTS

Tell children about what has just been discovered and the research in progress (with emphasis on what is still to be discovered) would be a means to stimulate curiosity and desire to participate in the S&T process.

- **Supportive elements:**

Osborne Attitudes towards science "In essence, the vision that school science offers is a backward-looking view of the well-established scientific landscape, whereas, in contrast, what appeals to and excites students is the 'white heat' of a the technological future offered by science. In short, to capitalize on students' interests, school science needs to be less retrospective and more prospective."

3.12. OTHER LEADS:

Give incentive to S&T institutions to communicate: as an example, link grants to the obligation to devote a percentage to communication. This type of policy has already been implemented (see EU 6th Framework Programme)

Alternative routes to HE (see Rand p53), a second chance to chose S&T after having chosen against it in HS.

Mecanical tools: (ex on entry requirements, grants and loans)

Actions directed towards particular target groups: female, students coming from low-income families

Managing by the cost (loans, grants, tuition fees…): would be ineffective?

Plan intervention as a system-wide event

4. ANALYSIS OF POSSIBLE REMEDIES BY CATEGORY

In this part, we describe the possible remedies relating to each category of factors (Image of S&T and S&T professionals, Image of S&T careers, S&T Education and curricula, S&T teachers, Gender and minorities issues).

For each group of factors, we extract from the causes analysis the factors that appeared both to have the strongest impact and to be the most actionable. Those are called the "Targeted factors".

Then, we describe the "Tools", or actions, that seem best able to address these factors.

Finally, we give, for each group of factors, some examples of remedies that are relevant with the kind of actions described. For each example of remedies only a short summary will be given and more extensive information is to be found in the Annexe.

4.1. IMAGE OF S&T AND S&T PROFESSIONALS

4.1.1. Targeted factors

- Improve the image that the children have of S&T utility to the society
- Improve the image that the children have of S&T professional's status
- Increase the knowledge that the children have of the diversity of S&T professionals: in terms of professions, lifestyles, identity (being from all types of backgrounds and minorities)
- Increase the knowledge that the children have of the reality of S&T and its elaboration processes
- Give children a chance to associate positive emotion to these subjects professions

4.1.2. Tools

- Promote an embodied perception of these professionals by giving children opportunities to actually meet them or through media. Visiting the workplaces and facilities (industries, laboratories) may help this process of embodiment too.
- Encourage the teachers to participate in promoting this knowledge and image. (This implies to foster also teachers' access and perception of Today's S&T and S&T professionals)
- Special care should be given to the message transmitted by the media, S&T professional associations and representative on the difficulties met by the profession (such as funding issues)
- Encourage entertaining activities about S&T and initiatives that associate pleasure and positive emotions with S&T and S&T professionals
-

4.1.3. Examples of remedies

5.Radboud

Relevant aspects:

PR policy

Specific objectives

- to break through the largely negative image of courses in the exact sciences, as research had revealed that potential students describe science studies as 'too difficult', 'too theoretical' and 'too specialist'. Moreover, most students felt that courses in the exact sciences offered a rather limited job perspective. They often depicted these perspectives as laboratories in which boring tests were carried out all day

- to improve the interface between secondary and higher education

Actions

- a magazine for school youth interested in science courses (‘B for you’)
- a special website for prospective students (‘Place to B’)
- intensified contacts with secondary school teachers in the region
- a study into the choice of studies of pupils was carried out. All the used PR- and enrolment activities were geared to the results of this research
- besides, also the results of the IOWO enrolment monitor (1996-2004) were used

10.Science partnership programs

Funding of selected programmes aimed at providing opportunities for secondary schools students and science teachers to gain familiarity with the frontier S&T researches and products

12.Europhysics fun

EuroPhysicsFun is a bottom-up initiative that establishes groups of edutaining students at European universities performing outreach activities. The shows have huge success. EuroPhysicsFun offers a complete package containing workshops, disseminating communication, and performance tools to the local "satellites", and tools to attract local funding. EuroPhysicsFun satellites are connected in web based and human networks.

13.Promoscience

PromoScience is a program operated by Canada’s Granting Agency for university and college research in the natural sciences and engineering (NSERC). It provides support for organizations 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 organization. PromoScience grants support organizations 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 to our young people.

14.Let’s talk science

Through its national volunteer-based program, Let's Talk Science provides a mechanism to expand the Science and innovation network and the skill set of volunteers, teachers and youth. Volunteers are given opportunities 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.

15. Actua

The mandate of ACTUA is to increase the scientific and technical literacy of young Canadians. Programs include summer day camps, in-school workshops, teacher training, community outreach activities and specialized programs for under-represented audiences. ACTUA publishes *YES,* a magazine aimed at kids to awaken and nurture their interest in science.

21.Ciencia viva

Relevant aspects:

1. **Network of Ciência Viva Centres**

A National Network of Ciência Viva Centres, designed as interactive spaces aimed at creating an awareness of science among the population.

2. **National scientific awareness campaigns**

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).

24.Giant Giant

One actor with his puppets and puppet theatre brings a simple and cute story for children where science and technology are brought under the attention of the children. Teachers are provided with a pedagogical dossier beforehand in order to allow them to prepare the performance. After the performance, the performer also engages the class in a conversation about the performance, thus allowing a deeper insight into what the children have learnt.

26.Eye Openers

The intention of the project was to provide a number of scientists and engineers willing to come to the classroom to talk about their profession, thus providing role models and an inside view of the "work floor".

28.Environment meeting pprogramme / Tessenderlo

Every year Tessenderlo Group sends out a delegation of its engineers to speak about their passion for chemistry to youngsters of 14-15 years of age. These "teachers for one day" worked within the action plan "Chemistry and Youth" of the Belgian chemical federation "Fedichem".

Since 1999 Tessenderlo Group invites in its West-Limburg Plants children from the local schools, 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.

29.Campaign "do not stay behind, follow sciences"

Media campaign to provide youngsters with an insight of what S&T really is, what possible professions there are, what educational background they should have for what kind of (S&T) studies, …

31.Flemish Science Week

The Science Week consists of four important parts :

- Science festival : the science festival is aimed at the general public and provides various hands-on activities, competitions, science theatre, quizzes, etc.
- Science through the looking-glass : an interactive program organised at universities, institutions for higher education and scientific institutions, aimed at youngsters aged 16 to 18.
- Science project : one week of interactive science for children aged 10 to 12 and organised around one theme.
- Projects organised by third parties : Observatories, scientific foundations, public libraries, etc. organise interactive scientific activities at their own location and imbedded in there normal programme.

33."About Life"

The broadcasts features exciting documentaries about recent scientific achievements that are closely related to the everyday experiences of the average citizen. Each edition of the programme is built around a prominent scientist who has been responsible for an important scientific breakthrough in his specialist field.

40. Multimedia award

A competition aimed at generating innovative ideas, centred around a central theme (for instance : timesaving Internet applications).

42. Science Korea

The Science Korea core project is "Science Culture City" which includes:

1) Establishment and management of "Everyday Science Classroom" in order to facilitate contacts of the public with scientific elements in everyday life
2) Building "Science Online Community"(Sci-Net) for the popularisation of science and technology through online media
3) Management of "Youth Science Club" in order to promote scientific activities of young pupils in primary and secondary school

The "Science Korea" project includes other various activities such as science popularisation projects using mass media, public science events, "Science for Leaders" program etc. This project tries to contribute to the expansion of scientific mind and culture among general public and the increase of the interests in science and technology among general public, especially among younger people.

49. NSF initiatives (US)

Informal Science Education

The NSF Informal Science Education program invests in projects that develop and implement informal learning experiences designed to increase interest, engagement, and understanding of science, technology, engineering, and mathematics (STEM) by individuals of all ages and backgrounds, as well as projects that advance the theory and practice of informal science education. Projects may target either public audiences or professionals whose work directly affects informal STEM learning.

Research Experiences for Undergraduates

The NSF Research Experiences for Undergraduates (REU) program supports active research participation by undergraduate students in any of the areas of research funded by the National Science Foundation. REU projects involve students in ongoing research programs or in research projects designed especially for the purpose.

4.2. IMAGE OF S&T CAREERS

4.2.1. Targeted factors

- Improve Young People knowledge of S&T careers in their diversity
- Improve Young People perception of the income level and social position associated with these careers
- Improve Young professionals integration
- Improve Young People knowledge of non-S&T careers with a high S&T content ?

4.2.2. Tools

At Primary and lower secondary levels:
- Meeting professionals
- Job experiences (internships, summer jobs…)
- Communication

At upper secondary and tertiary levels:
- Career guidance actions
- Contacts with alumni
- Collecting real information (e.g. alumni surveys) and communicating on it.

Improve the financial status of those working in publicly funded research and the number of positions offered (and communicate on it)

4.2.3. Examples of remedies

5.Radboud

Relevant aspects:

Public Relations policy:

- a magazine for school youth interested in science courses (‘B for you’)
- a special website for prospective students (‘Place to B’)
- intensified contacts with secondary school teachers in the region
- a study into the choice of studies of pupils was carried out. All the used PR- and enrolment activities were geared to the results of this research

Intensification of contacts with the business world

- Professors to occupy endowed chairs have been recruited from the business world, to make the courses more application-oriented and more topical
- the formation of businesses is stimulated and the exchange of knowledge from the university to the businesses and vice versa is facilitated by means of the university business centre and the Mercator Technology & Science Park
- the PR materials increasingly offer information about the occupational practice of science graduates

- the curriculum has been changed drastically to offer students a better preparation for the labour market

- the content to be given to the Communication/Education & Management specialization profiles will also offer opportunities for other than the traditional research positions

7. Women give new impetus to technology (Germany)

An organism collecting funds and developing projects related to the promotion of women in technology. Among projects and campaigns realized or coordinated by them: "career orientation day for girls", "be.it and be. Ing (information about the jobs profiles and degree courses in IT and Engineering), teacher@D21 (stimulating teachers contacts with companies in order to improve their career guidance ability).

13 Promoscience

PromoScience grants support organizations 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 to our young people.

21.Ciencia viva:

Relevant aspects:

- CV supports short placements for students in research laboratories

- CV includes a programme fostering the twinning between schools and scientific institutions

- CV includes **a programme for the scientific occupation of teenagers : "Science in the Holidays for Young People" provides work experiences for the students in research laboratories during one or two weeks in the summer holidays. 4 000 secondary school students had the opportunity to participate since 1997**

- National Scientific Awareness Campaigns stimulate and provide the opportunity for personal contact with science specialists and institutions in the different fields. These initiatives provides interaction with specialists. Each summer, field activities are organized 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, starting in 2004, visits to engineering facilities like bridges and dams, power stations, antennas are available for a non specialized public.

26.Eye Openers

The project was presented as one of several within the Innovation action paper. Two other projects from the action plan in this respect were "A taste of your future" and "Future breakfast".

Intention of the project was to provide a number of professionals willing to come to the classroom to talk about their profession. According to our own analysis and a study of 2002 (in the framework of the Dream-it-project ; see www.dream-it.be) pupils in the last year of secondary education express a real need in this respect.

Objectives : to provide the target group (at school) with the real life experience of the job they are interested in.

Evaluation : although 128 speakers were available providing a wide range of topics, only one person was contacted to talk in a class. It is possible that the other two projects mentioned earlier were of greater interest to the teachers.

28.Environment meeting programme / Tessenderlo

- Every year Tessenderlo Group sends out a delegation of its engineers to speak about their passion for chemistry to young people of 14-15 years of age. These "teachers for one day" work within the action plan "Chemistry and Youth" of the Belgian chemical federation "Fedichem".

- Since 1999 Tessenderlo Group invites in its West-Limburg Plants children from the local primary schools, as part of a national program to enhance the children's awareness for the environment. The children can visit the water purification installations and perform some laboratory tests.

- Other educational projects have the company active support, such as the "mini-enterprises" to make 16-year olds familiar with professional life and to prepare them for later entrepreneurship.

29.Campaign "do not stay behind, follow sciences"

- Media campaign to provide youngsters with an insight of what S&T really is, what possible professions there are, what educational background they should have for what kind of (S&T) studies,

44. A mapping of production and employment

This study identifies the career patterns of the 7678 persons that received a five year degree from one of the Danish universities during the 30 year period from April 1, 1971 to October 1, 1999 within the mathematical sciences, the physical sciences, and the chemical sciences. Statistics on production, employment spectra, durations of studies are presented as function of time. The material is used for career advice, etc. addressed at pupils finishing secondary school.

46 Jet-Net

Jet-Net participants, a wide variety of industry and technology sectors such as petrochemicals, defence, food, ICT, metals, electronics and instrumentation, offer a broad range of inputs which constitute the main ingredients of tailor-made programmes set up jointly with schools.

Among them, they provide **career orientation suppo**rt (assistance to students in their individual choices) and various opportunities to meet professionals from the participant companies.

49. NSF initiatives (US)

Research Experiences for Undergraduates

The NSF Research Experiences for Undergraduates (REU) program supports active research participation by undergraduate students in any of the areas of research funded by the National Science Foundation. REU projects involve students in ongoing research programs or in research projects designed especially for the purpose.

4.3. S&T CURRICULUM

4.3.1. Targeted factors

- Build up intrinsic motivation towards S&T: pleasure, positive strengthening, gratifications

- Build up Young People confidence in their ability to succeed in S&T, especially among girls, economically less-privileged, and minorities.

- Strengthen the link between what is taught and what Young People care for: relevance to their life and/or to the Society

- Situate S&T in their larger environment: make a larger place for general education, soft/professional skills, and the social construction of S&T

- Broaden the scope of the S&T taught to avoid over-specialization

- Give more flexibility in the choice process

4.3.2. Tools

- Encourage practical and experimental approach

- Promote the teaching of contextualized science

- Design new tertiary education courses with broader range of knowledge within S&T and with more focus on general education and soft/professional skills

- Design specific courses to allow Young People that went out from the S&T path to come back into the S&T studies

- Increase specific funding for PhD students and post-docs

- Promote the view of S&T subjects in secondary education as part of general education for all and not only towards tertiary education in sciences

4.3.3. Examples of remedies

<u>1. La main à la pâte</u>

Volunteer teachers have been trained and given support to teach science in a more practical and interactive way.
In 2000 a countrywide programme for the "renewed teaching of S&T" was launched by the minister of education, based on the experience gained during the operation "la main à la pâte".

The Program includes different actions, such as :

- Increasing the part of science in the continuous training of teachers.

- Sharing out money (about 40 MF so far), 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 program involves also the creation of comities (national level and also at the different local levels: the so called "Académies" and their subdivision, the "Départements"). The aim of these comities is to organize the cooperation among the actors of the program, that is: directors of education, inspectors, institutes for teachers' training, scientific institutions.

In 2001-2002, a new curriculum was issued, coherent with the programme for renewed teaching. The emphasis is on the method, based on the pupils' questioning and experimental investigation. Group work is encouraged.

2. Tertiary level education with economic support for adults

Financial support (grants and loans with favorable conditions) given to targeted people (adults having not studied in S&T, 28-48 year old, full employment for at least 5 years). A total of 10 000 students have benefited from this support.

3.The technical-scientific basic year

Objectives: Giving "second chance to choose science studies" to students having elected other fields at high school. For this, a special year has been set up to permit students that didn't study science at high school to build the science knowledge they need to be admitted in tertiary level science courses.

5. Radboud

Relevant aspects:

- Tutor system

  Specific objectives
  - to improve the interface between secondary and higher education

  Actions
  - 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 university lecturers about the used didactics and the extent to which the material discussed in the lecture connects to what the students have learnt before

  Results
  - considered useful by almost all involved parties
  - increase of credits earned
  - a trend study (IOWO, 2003) has shown that the interface between secondary and university education has improved considerably over the past few years, also in the perception of the students
- Innovation of courses offered

  Specific objectives
  - attract potential students with broader scientific interests

  Actions
  - new trans-disciplinary courses: general natural sciences, molecular life sciences, information science and environmental sciences

  Results

the introduction of these courses has attracted many new students

- Formation of clusters

  Specific objectives
  - To break in the pronounced compartmentalisation of the various courses

  Actions
  - the set-ups of bachelor studies were made uniform to the greatest possible extent and organized into educational clusters

  Results
  - science students are enthusiastic about these clusters
  - link up more adequately to the interests of first-year students

- students can transfer more efficiently to another course within the faculty
- improved cooperation between the various courses
- problems of coordination have been largely overcome

- Introduction of new teaching methods

  Specific objectives
  - to emphasis the acquisition of general skills such as:
    - communication and cooperation
    - the ability to deal with large quantities of information and their application

  Actions
  - the teaching material is offered increasingly in a project-oriented and context-linked manner

  Results
  - the majority of the science students are enthusiastic about the new methods
  - by now, faculty professors have developed a greater educational awareness, but the realisation of the cultural switch aspired by the faculty board, turned out to be a laborious process
  - learning items:
    - It is better to realise these changes in a process-oriented manner, making it possible to prioritise matters
    - It is important to develop specific human resource management in which more attention is paid to the didactic qualities of new employees/professors
    - Clarity about the division of research- versus teaching tasks should be aspired

- Introduction of specialization options

  Actions
  The bachelor-master structure was introduced for all studies. This structure consists of a broad three-year bachelor cycle, followed by a two-year specialised master cycle. The master's course offers three specialization profiles: Research (R), Communication/Education (C/E) and Management (M).

- Intensification of contacts with the business world

  Actions
  - professors to occupy endowed chairs have been recruited from the business world, to make the courses more application-oriented and more topical
  - the formation of businesses is stimulated and the exchange of knowledge from the university to the businesses and vice versa is facilitated by means of the university business centre and the Mercator Technology & Science Park
  - the PR materials increasingly offer information about the occupational practice of science graduates
  - the curriculum has been changed drastically to offer students a better preparation for the labour market
  - the content to be given to the CE/M specialization profiles will also offer opportunities for other than the traditional research positions

8. Model schools

In designated schools, promotion of comprehensive S&T education with focusing on observations and experiments, enrichment of elective subjects and advanced learning

9. Super Science High Schools

Special programme focus on science, mathematics and technology, with emphasis on cooperative measures with universities and research institutes.

10. science partnership programs

Funding of selected programmes aimed at providing opportunities for secondary schools students and science teachers to gain familiarity with the frontier S&T researches and products

11. Science team K

Scope: One secondary school and 17 surrounding primary schools in a minor provincial town, Kalundborg, have been selected.

Goal: 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.

Actions: A spectrum of remedies are implemented, partly inspired by the CienciaViva experience, including funding of teachers' innovative ideas. 65 science teachers are actively engaged. Local industrial companies are involved

14.Let's talk science

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.

15. Actua

ACTUA is a national, not-for-profit organization and registered charity. The mandate of ACTUA is to increase the scientific and technical literacy of young Canadians. Programs include summer day camps, **in-school workshops**, teacher training, community outreach activities and specialized programs for under-represented audiences. ACTUA publishes *YES,* a magazine aimed at kids to awaken and nurture their interest in science.

20.University reform (Italy)

Following the Sorbonne and Bologna declarations, Italy in 1999 has reformed radically its University Regulations and structures into a system of 3+2+3 cycles of studies. The increase of student's enrolment had been steady at a rate of about 6-8% per year. Most Faculties of Science have experienced a higher rate of increase.

21.Ciencia viva

Relevant aspects:

Ciencia Viva in schools

Ciência Viva provides support to education projects to develop practical activities and to promote science and technology culture in basic and secondary education schools.

For this purpose three main lines of action were launched:

- an annual national project competition in the field of scientific education,
- a programme fostering the twinning between schools and scientific institutions
- a programme for the scientific occupation of teenagers : *"Science in the Holidays for Young People"* provides work experiences for the students in research laboratories during one or two weeks in the summer holidays.

25.Chip, chip, chip, hurray

Interactive experimental box about ICT and introducing chips for use in the classroom. This box is comparable with the educational experiment boxes, 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. From the analysis of policy and the action plan and some of the activities (see report “causes and remedies for Flanders”, available on the OECD-website) we leant that the educational experiment boxes were sometimes left aside, just because such a helpdesk was lacking. It is one of the merits of this project that it provides such a service and fills in a gap that was detected during the analysis.
The project is specifically developed for Technological education and provides for one of the topics of the framework envisioned by the TOS21-project, namely ICT, a sound starting base to fill in a whole educational trajectory (from 2,5 years old to 18 years old). It is the intention of the actor responsible to provide for the whole trajectory and also introducing nanotechnology.

27. ICT platform 32.Educational experiment boxes campaign

The project provides a platform for pupils and their teacher to introduce ICT in education in accordance with the age group and in correspondence with the attainment targets. The platform consists essentially of three subprojects : the ComiX-files (1st stage of secondary level (12-14)), Stimulus (a virtual science class for the second stage of secondary education (14-16)) and the Virtual Museum (3rd stage of secondary education (16-18)).

- ComiX : pupils use comics to find and decode the scientific experiments of the heroes in the comic books. A number of mysteries have to be solved and the final solution be presented. The project is built as a competition. In the three editions, more than 7000 pupils participated. (http://comix-files.vub.ac.be/ (in Dutch)).
- Stimulus : is an educational computer game for beta sciences. It is built up around a central theme, with different modules. At the moment one module in chemistry is available : “the fireworks factory”, that welcomed 4000 visitors. A second module for chemistry (“the washing machine”) will become available in September 2005. The development of modules in other subjects is envisioned in the short term. (http://stimulus.vub.ac.be/ (in Dutch))
- Virtual Museum : in co-operation with teachers, scientists and multimedia specialists pupils investigate a certain aspect of Brussels. The result of their investigation is translated to a mini-site who has an exposition room at the virtual museum.

32. Educational experiment boxes campaign

Nine activities in one box aimed at making science and technology accessible to the pupils. Experiment for instance with a polarization filter, sound in a vacuum, refraction & 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.

42. Science Korea

Management of “Youth Science Club” in order to promote scientific activities of young pupils in primary and secondary school

45.Integrating Technology in Primary Education

A programme, first developed by Axis as a pilot and later enlarged to all primary schools. It promotes the teaching of S&T at primary schools and the evaluation of practical skills.

At the national level: engineering and technology have been added to the core objectives of primary education and are tested in the primary school final test. Financial incentive have been set up to encourage school to adapt to this additional objective.

The project included instruments for the dissemination of good practices and materials on a large scale, a regional infrastructure supporting schools in implementing these tools and a quality improvement system.

46. Jet-Net

A network formed by a wide variety of companies to assist secondary schools in making science subjects more appealing to students aged 14–18 and to clarify future career prospects in the industry.

A broad range of activities including general introduction and familiarization (company excursions, presentations), subject support (assistance to teachers in specific parts of the curriculum), career orientation support (assistance to students in their individual choices).

47. Redesign in vocational education

A project aimed at developing more attractive vocational education through the redesign of courses.
This includes:
New teaching methods (Mentoring, starting with practice, use of ICT, emphasis on the context,)
Broad and flexible learning-routes (multi-technical or cross-sectoral programmes)
Continuous learning line (improve the connection between the various levels of vocational education)

49. NSF initiatives (US)

Instructional Materials Development Program – IMD (Primary/Secondary Education)

This program supports:
- the creation of Instructional frameworks centered on learning progressions,
- the creation and substantial revision of comprehensive curricula and supplemental instructional materials,
- the creation of tools for assessing student learning that are tied to nationally developed standards and reflect the most current thinking on how students learn mathematics and science,
- the research for development of the IMD program and projects

Course, Curriculum, and Laboratory Improvement Program - CCLI (Tertiary education)

This program seeks to improve the quality of science, technology, engineering, and mathematics (STEM) education for all undergraduate students. Based on a cyclic model of knowledge production and improvement of practice, CCLI supports efforts that conduct research on STEM teaching and learning, create new learning materials and teaching strategies, develop faculty expertise, implement educational innovations, assess learning, and evaluate innovations.

4.4. TEACHERS AND TEACHERS TRAINING

4.4.1. Targeted factors

Primary teachers

- Specific S&T training

Secondary teachers

- Making teaching an attractive career for S&T students
- Expanding the supply pool of S&T teachers
- Ensuring that teachers have the required knowledge and skills
- Meeting with S&T other professionals (Insertion in a broader community, better knowledge of up-to-date S&T, sense of utility and valorisation)
- Providing incentive to stay in school for teachers of short supply subject areas

Tertiary teachers

- Develop a didactic of S&T for Tertiary education. Make links between Education departments and SME department
- Increase Higher Education teachers awareness of the importance of encouraging teaching vocations among their students

4.4.2. Tools

Making teaching an attractive career choice for students of S&T courses:

- improving teaching salary competitiveness and employment conditions
- improving entrance conditions for beginning teachers (Location, hours, mentoring and counselling…)
- improving the image and status of teaching
- Transforming teaching into a knowledge-rich profession

Expanding the supply pool of S&T teachers:

- Alternative routes to S&T teachers education for career changers
- Special recruitment procedures for S&T teachers. For example, previous working and study experience can be considered for certification or recruitment. This can be observed especially for vocational education teachers.

Ensuring that teachers have the required knowledge and skills

- Developing teacher profiles that indicates what teachers are expected to know and be able to do
- Viewing S&T teacher development in the lifelong learning perspective to keep up with the rapid change in schools and in S&T knowledge

- Integrating professional development throughout the career: In some countries, too much emphasis is put on initial teacher development, or in-service/continuing training is fragmented. Initial teacher education should be regarded as the foundation of teacher development rather than providing everything for teachers. Teachers should be given incentive and opportunity for professional development throughout their career. Each stage of teacher education and professional training needs to be interconnected.

In subjects where there is a shortage of teachers, providing incentives to encourage them to stay:

- Making reward mechanisms more flexible
- Evaluating and rewarding effective teaching
- Improving competitiveness of benefit package (e.g. better working conditions, more flexible working hours and employment as part-time employment or leave programmes (sabbatical, maternity etc.).)

4.4.3. Examples of remedies

1. La main à la pâte

Volunteer teachers are trained and given support to teach science in a more practical and interactive way.
In 2000 a countrywide programme for the "renewed teaching of S&T" was launched by the minister of education, based on the experience gained during the operation "la main à la pâte".

At the beginning, an initiative from Georges Charpak and the French Academy of Science to renew science teaching in French pre-primary and primary schools. It functioned on the basis of volunteer teachers that where trained and given support to teach science in a more practical and interactive way.

In 2000 a countrywide programme for the "renewed teaching of S&T" was launched by the minister of education, based on the experience gained during the operation "la main à la pâte".

The Program includes different actions, such as :

- Increasing the part of science in the continuous training of teachers.
- Sharing out money (about 40 MF so far), 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 program involves also the creation of comities (national level and also at the different local levels: the so called "Académies" and their subdivision, the "Départements"). The aim of these comities is to organize the cooperation among the actors of the program, that is: directors of education, inspectors, institutes for teachers' training, scientific institutions.

In 2001-2002, a new curriculum was issued, coherent with the programme for renewed teaching. The emphasis is on the method, based on the pupils' questioning and experimental investigation. Group work is encouraged.

4.NOT

The work within the project has been organized in a number of activities.

- The project has for instance supported:
  - in-service training of teachers and teacher trainers,
  - series of seminars for teacher trainers at the university institutes of education,

- regional conferences on science education in cooperation with the National Resource Centres,
- parents´ meetings called ”the active parents´ meeting”
- specific studies on related subjects

- The project has established regular contacts with about one fourth of the local districts in the country, (= 70 districts), so-called SciTech districts, to encourage local activities in the SciTech field.
- The SciTech paper, in Swedish called NOT-bladet, is published 4 times a year in 20.000 copies for information and inspiration for all people working in the SciTech field.

5.Radboud

Intensification of contacts with the business world:

Actions

- professors to occupy endowed chairs have been recruited from the business world, to make the courses more application-oriented and more topical
- the formation of businesses is stimulated and the exchange of knowledge from the university to the businesses and vice versa is facilitated by means of the university business centre and the Mercator Technology & Science Park
- the PR materials increasingly offer information about the occupational practice of science graduates
- the curriculum has been changed drastically to offer students a better preparation for the labour market
- the content to be given to the CE/M specialization profiles will also offer opportunities for other than the traditional research positions

6.Sinus

This federally sponsored program was set up in August 1998 in 15 "Bundesländern" (federal states) and aims to establish permanent quality development practice in schools. In this pilot program, teachers develop their lessons autonomously but with academic support. They cooperate in regional networks where they plan, discuss and evaluate their teaching strategies

7. Women give new impetus to technology

An organism collecting funds and developing projects related to the promotion of women in technology. Among projects and campaigns realized or coordinated by them: “career orientation day for girls”, “be.it and be. Ing (information about the jobs profiles and degree courses in IT and Engineering), teacher@D21 (stimulating teachers contacts with companies in order to improve their career guidance ability).

10. Science partnership programs

Part of the national project called “Science Literacy Enhancement Initiatives”
Funding of selected programmes aimed at providing opportunities for secondary schools students and science teachers to gain familiarity with the frontier S&T researches and products

11. Science team K

Scope: One secondary school and 17 surrounding primary schools in a minor provincial town, Kalundborg, have been selected.

Goal: 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.

Actions: A spectrum of remedies are implemented, partly inspired by the Ciencia Viva experience, including funding of teachers' innovative ideas. 65 science teachers are actively engaged. Local industrial companies are involved.

13.Promoscience

PromoScience is a program operated by Canada's Granting Agency for university and college research in the natural sciences and engineering (NSERC). It provides support for organizations 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 organization. PromoScience grants support organizations 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 to our young people.

14.Let's talk science

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.

Professional development workshops and conference presentations meet provincial curricula demands and are designed to increase a teacher's confidence and knowledge in Science so that s/he can provide their students with a stimulating Science learning environment.

Volunteers are given opportunities 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.

15. Actua

Programs include summer day camps, in-school workshops, **teacher training**, community outreach activities and specialized programs for under-represented audiences. ACTUA publishes *YES,* a magazine aimed at kids to awaken and nurture their interest in science.

21. Ciencia Viva ?

Ciencia Viva in schools

Ciência Viva provides support to education projects to develop practical activities and to promote science and technology culture in basic and secondary education schools.

For this purpose three main lines of action were launched:

- an annual national project competition in the field of scientific education,
- a programme fostering the **twinning between schools and scientific institutions.**
- a programme for the scientific occupation of teenagers : "Science in the Holidays for Young People" provides work experiences for the students in research laboratories during one or two weeks in the summer holidays

23. TOS21

The project will provide the framework for better education in technology, a framework that will be used in other projects in order to better co-ordinate and structure the activities. The participation of the educational networks is essential for the realisation of the project, hence they will be involved at an early stage in order to obtain a framework that is agreed by all the actors involved.

25.Chip, chip, chip, hurray

Interactive experimental box about ICT and introducing chips for use in the classroom. The boxes are provided with support for the teacher, meaning that there is permanent helpdesk available. A demonstration session is given and a service desk is available for teachers when they try the box on their own.

27.ICT platform for pupils and teachers

The project provides a platform for pupils and their teacher to introduce ICT in education in accordance with the age group and in correspondence with the attainment targets.

32.Educational experiment boxes campaign

Nine activities in one box aimed at making science and technology accessible to the pupils. Experiment for instance with a polarization filter, sound in a vacuum, refraction & 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.

35. teachers in-service training

The teacher in-service training was an implementation of the LUMA programme. Each year, the universities´subject departments, departments of teacher education and training schools have been able to apply for the supplementary training allocations set aside for this purpose. Many in-service courses have related to information and communication technology. Many projects have included research activity and the production of net material suitable for teaching.

The other subjects of the training events were, e.g. mathematics and natural sciences contents in pre-school education, mathematics in remedial teaching and the development of the teaching of mathematics and natural sciences subjects at training schools.

49. NSF initiatives (US)

Teacher Professional Continuum - TPC (Primary/Secondary Education)

This program addresses critical issues and infrastructure needs regarding the recruitment, preparation, induction, retention, and life-long development of K-12 science, technology, engineering, and mathematics (STEM) teachers. Its goals are to improve the quality and coherence of teacher learning experiences across the continuum through research that informs teaching practice and the development of innovative resources for the professional development of K-12 STEM teachers. The program supports Research Studies, Resources for Professional Development, and Conferences and Symposia.

Math and Science Partnerships - MSP (Primary/Secondary education)

This program was launched in 2002, in order to participate in the No Child Left Behind initiative.

It supports the development, implementation and ultimate sustainability of promising partnerships among institutions of higher education, K-12 schools and school systems and other important stakeholders to:

- ensure that all K-12 students have access to, are prepared for and are encouraged to participate and succeed in challenging and advanced mathematics and science courses;
- **enhance the quality, quantity and diversity of the K-12 mathematics and science teacher workforce;**
- and develop evidence-based outcomes that contribute to our understanding of how students effectively learn mathematics and science.

CAREER Program (Tertiary)

This programme support of the early career-development activities of those teacher-scholars who most effectively integrate research and education within the context of the mission of their organization.

4.5. GENDER AND MINORITIES

For this subject, many factors are not very easily actionable as they relate to family background, culture, peer effects. This restricts the range of targeted factors and remedies to be proposed.

4.5.1. Targeted factors

- Adapt the learning context and approach to make it more attractive to female students and those from minority background
- Provide female students and those from minority background 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

4.5.2. Tools

Adaptation of the offer to these targets :

- Include in S&T subjects a significant quantity of general education (including economy, politics…)
- Promote broader subjects with contextualization and multi-disciplinarity
- Put a stronger focus on the relation between what is taught and the Society and on the utility of what is taught
- Put a stronger emphasis on soft skills (communication, team working, planning, project management, languages…)
- Promote teaching methods that includes more interactions
- Design education paths that provides opportunity to enter the job market at various stages

Mentoring projects to support the careers of women in science and engineering (for instance in Germany: http://www.kompetenzz.de/netzwerke/forum_mentoring)

Study programs only for women at some universities

Support programmes (see www.kompetenzz.de)

Non co-educative schools or classes: contrasted results – no consensus [86]

[86] Osborne Attitudes towards science: Contrary to popular belief that more girls choose to study science in a single-sex environment, two more recent studies – the youth cohort study conducted by Cheng, Payne and Witherspoon (1995) and a study based on questionnaire responses from 722 schools (Sharp, Hutchison, Davis, and Keys 1996) – both found that the uptake of physical science by girls in single sex schools was not higher than co-ed schools.

4.5.3. Examples of remedies

2. Tertiary level education with economic support for adults

Financial support (grants and loans with favorable conditions) given to targeted people (adults having not studied in S&T, 28-48 year old, full employment for at least 5 years). A total of 10 000 students have benefited from this support.

The programme broadened the recruitment basis of students in S&T. This action was aimed at a population that would not have normally had access to high level S&T education.

7. Women give new impetus to technology

An organism collecting funds and developing projects related to the promotion of women in technology. Among projects and campaigns realized or coordinated by them: “career orientation day for girls”, “be.it and be.Ing (information about the jobs profiles and degree courses in IT and Engineering), teacher@D21 (stimulating teachers’ contacts with companies in order to improve their career guidance ability).

13.Promoscience

PromoScience is a program operated by Canada’s Granting Agency for university and college research in the natural sciences and engineering (NSERC). It provides support for organizations 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 organization. PromoScience grants support organizations 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 to our young people.

15. Actua

Programs include summer day camps, in-school workshops, teacher training, community outreach activities and specialized programs for under-represented audiences. ACTUA publishes *YES,* a magazine aimed at kids to awaken and nurture their interest in science.

17.Computer class for women only

Nortel has run an **experimental project** in one school in which classes were set up in secondary school computer science along gender lines, i.e. some classes for girls only, and other predominantly male. The results of the experiment are positive and illustrate one potential solution to the problem of lack of interest in computer science by this segment of the population

Objectives:

- To encourage more women to enroll in computer science class

Actions:

- classes for female only (3)
- the course provides Internet programming in place of the standard programming languages

30.The great sEXPERIMENT

This exhibition brought some interesting information about the so-called talents of males and females that are in most cases strongly attributed to one of the sexes (for instance the fact that women cannot read maps or can perform more than one task at the same time). Visitors had a unique barcode and they could test these hypothesis or statements themselves. Afterwards the scores of all visitors were statistically arranged.

49. NSF initiatives (US)

Louis Stokes Alliance for Minority Participation (LS-AMP)

This program is aimed at increasing the quality and quantity of students successfully completing science, technology, engineering and mathematics (STEM) baccalaureate degree programs, and increasing the number of students into programs of graduate study. LSAMP supports sustained and comprehensive approaches that facilitate achievement of the long-term goal of increasing the number of students who earn doctorates in STEM fields, particularly those from populations underrepresented in STEM fields.

Research in Disabilities Education (RDE)

This program supports efforts to increase the participation and achievement of persons with disabilities in science, technology, engineering, and mathematics (STEM) education and careers. Meritorious projects from a diversity of institutions are supported via the RDE Demonstration, Enrichment, and Information Dissemination (RDE-DEI) program track. Promising research efforts are also developed further via awards under the Focused-Research Initiatives (RDE-FRI) program track. In the third program track, broadly applicable methods and products are disseminated for widespread use, commercialization, or inclusion in the activities of program-sponsored Regional Alliances for persons with disabilities in STEM education (RDE-RAD). RDE Alliances serve to inform the public, government, and industry about proven-good practices in the classroom, promote broader awareness of disabilities issues, and define specific areas of accessibility and human learning in need of further attention by educators and the research community.

Research on Gender in Science and Engineering Program:

The program seeks to broaden the participation of girls and women in all fields of science, technology, engineering, and mathematics (STEM) education by supporting research, dissemination of research, and extension services in education that will lead to a larger and more diverse domestic science and engineering workforce. Typical projects will 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 will disseminate and apply findings, evaluation results, and proven good practices and products.

5. ACTION PLANS

“Remedies” often appear fragmented and may be unable to reach a critical mass that could make a real difference.

Some countries have opted for a broader and integrated approach to address the issue. This has translated in various action plans. These action plans are dealt with separately here as they aggregate various actions aimed at addressing the issue in many different ways.

5.1. INSTIGATORS AND SCOPE

Action plans may be originated by various stakeholders. The state, the region, a funding institution…

5.2. TYPES

Action plans may be organized on a bottom-up or top-down pattern

On the **bottom-up** side, we find the “**call for proposals**” type. It consists in drawing 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 case, the funded projects will be followed and assessed but the instigators often do not have anymore the power to act upon the implementation or to impact the process. In some cases, a “contract of objectives” can be negotiated and formalized between the funding organization and the project leaders. Then, the funding may me partly subordinated to the reaching of the objectives.

On the **top-down** side, the instigators design a set of specific actions, designate the actors in charge of implementing them and monitor the output. In the best situation, the top-down approach is build on the basis of a previous consultative and participative process in which the different stakeholders have elaborated the fundamentals of the action plan.

In many cases, the action plan structure integrate both approaches with part of the plan being implemented on a top-down pattern and part on a bottom up one.

5.3. MANAGEMENT AND EVALUATION

Management may be delegated by the funding Institution to dedicated organizations that may already exist (for example in Japan, the Japan S&T Agency took responsibility for the “Science High Schools” component of “Science Literacy Enhancement initiatives or be created specifically for this task (for example the Platform in the Netherlands).

Whatever the approach, bottom-up or top down, the evaluation process is made difficult by the broad spectrum of actions generally involved in action plans.

5.4. EXAMPLES

8./ 9./ 10. "Science Literacy Enhancement Initiatives" (Japan)

This national project has been implemented since 2002 to increase the willingness of young people to learn about S&T. It includes among other three major initiatives (which are described in the remedies notes 8, 9 and 10) : Model Schools for promotion of Science Education, Super Science High Schools and Science partnership Programs.

According to our definition, this action plan is of a bottom-up kind as Government set the general goals and made funds available for local institution within a competition process.

The government delegated the management to specific agencies. For example, SSH (No.9) initiative is managed by the JST (Japan Science and Technology Agency) where comprehensive supports are given to individual schools.

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

18. Scientific degrees project (Italy)

This plan is aimed at arousing the interest of the population (and of the young in particular) in Science; decreasing the negative perception of Science as seen today by the layman. Its goals also include the promotion of scientific studies, upgrading teacher's training and careers and gender-oriented actions.

This action plan is of the bottom-up type as it took the form of a call for proposal based on the actions and general guidelines defined by a national working group.

The management of this project involves many actors. 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.

21. Ciencia viva (Portugal)

Ciência Viva develops its activities in three fundamental areas:

- Ciencia Viva in schools: support to education projects to develop practical activities and to promote science and technology culture in basic and secondary education schools.

- Network of Ciência Viva Centres: a national network, designed as interactive spaces aimed at creating an awareness of science among the population.

- National scientific awareness campaigns: National Scientific Awareness Campaigns stimulate and provide the opportunity for personal contact with science specialists and institutions in the different fields.

22. and 37: Action plan for Flanders and Yearly call for proposals for projects for the popularization of S,T and Innovation

The action plan is the top-down instrument used to implement the policy with respect to the popularisation of science, technology and innovation. The policy is outlined in the (yearly) policy letter which covers the whole policy with respect to STI. In the action plan the policy is described in more detail and the actions to be undertaken are described as well.

The call for proposals is the bottom-up instrument the Flemish Government uses (in the action plan for Science information and Innovation) in order to stimulate the actors in the field of the popularisation of STI to gain some expertise in this respect. The intention being that the actors become more and more involved in the action plan and to stimulate the bottom-up realisation of activities. Project or actors that are able to prove their worth by regularly scoring well with their proposals can become a (structural) partner within the action plan, meaning that they will receive financial support over a long period (3 to 5 years).

34. LUMA

In 1995, on the basis of the Finnish Government programme, the National Board of Education lauched a project to develop the teaching of mathematics and the natural sciences (the LUMA project).

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.

Schools, educational establishments and higher education institutions have engaged in co-operation. 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 have 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 approx. 20 man-years during the project to developing teaching in mathematics and the natural sciences

LUMA is constructed with both "top-down" and "bottom-up" approaches: top-down as the government sets the general goals, targets and funds available to local institutions and bottom-up as several different players (the municipalities, schools, educational establishments and higher education institutions) are involved, each with their own resources.

43: Delta Plan - National Action Plan on tackling the shortage of scientists and engineers

This National action plan has the objective of increasing S&T graduates by 15% between 2000 and 2010.

The targets were set top-down by the government as well as the first outline of the approach. But the policy making is done and has been done bottom-up. Based on the experiences in schools and companies in the past and present the programme is formed. Starting point is the schools own policy. A range of solution directions and methods has been developed with which schools can start changing things according to their own choices and insights. Innovation and performance agreements are made with the school or company regarding the ultimate objectives. The core of this approach, then, is the autonomy of the school. Nothing is imposed. Progress is monitored, and the results of monitoring are discussed with the school at auditing meetings, when the school as it were has a mirror held up to it so that it can see its strengths and weaknesses.

The government defined objectives in the National Action Plan on Science and Technology (Nationaal Actieplan Bèta/Techniek: 15% more new science and technology graduates in 2010 relative to 2000, and to ensure that scientists and technologists are more effectively retained and used. The Science and

Technology Platform (Platform Bèta Techniek) was established to implement, manage and further develop the plan. Their yearly plans have to be approved by the ministry of Economic Affairs, the ministry of Social Affairs and Employment and the ministry of Education, Culture & Science. The indicators of evaluation (there is a midterm evaluation in 2007) are proposed by the Platform and have to be approved by the ministries mentioned earlier.

41. Promotion of Young People into Science and Engineering (Korea)

This project is a trans-ministerial initiative of the Korean government in order to respond to the decline of young people's interests in science and technology and the decline of enrolment rate of talented young people into science and engineering fields.

This project is built on a top-down pattern.

Specific policy tasks have been implemented by relevant governmental ministries (e.g. Ministry of Education for the strengthening of mathematics and science education up to secondary education, Ministry of Science and Technology and Ministry of Education for the S&E education at colleges and universities etc.).

The program objective was defined by an inter-ministerial task force team, which was asked to prepare the policy recommendations for the problem of general decrease of interest in S&E education and research activities among young people. The team consisted of government officials and professionals from various fields (e.g. academia, S&E education, R&D policy etc.). The team's policy recommendations were ratified at the high-level government committee.

Each policy action from the program has been mainly managed by the relevant ministry and there has been no special team/organization for the implementation and management of the program. However, an upper-level government committee - National Science and Technology Council (NSTC) - has been monitoring the performance of the overall program regularly.

PART FIVE: POLICY RECOMMENDATIONS

Main targets for action are described in the chapter on remedies. The objective of this chapter is to draw up recommendations on how to transform this goals into policies, id est, how to ensure the proper conditions in order to implement effectively these actions.

1. PROPOSED POLICIES

1.1. A FOCUS ON EVALUATION OF ACTIONS

There is a need for more systematic evaluation of actions. The indicators to be assessed should be specified at the very beginning of the project. Existing evaluations are often restricted to count the number of people impacted by the actions and very rarely measure the nature and extent of their real impact.

1.2. CHAIN APPROACH

More coordination in action: to combine all actors' efforts and organize them.

Isolated actions cannot tackle a so complex issue. Need for a "critical mass" of actions

Make sure to act upon the different levels of Education in an integrated approach.

1.3. - A NEED FOR A MORE STRUCTURED ACTION AT THE INTERNATIONAL LEVEL ? (OECD?)

A structure to:

- monitor information/initiatives on this issue: follow-up of conferences, policies, studies, best practices, quantitative information, methodologies (especially on evaluation)…
- stimulate the communication around best practices, methodologies for evaluation, teaching material…
- stimulate interactions and networking between all actors involved

1.4. - A NEED FOR IMPROVED QUANTITATIVE TOOLS

Despite the many efforts conducted at the OECD in the field of education statistics, the current statistical system does not provide the breadth of information needed to study the trends in the number of students choosing certain disciplines. The OECD education database currently provides data on the number of graduates by field of education from 1998 to 2003 only. The database would greatly benefit from the following improvements:

- Data on new entrants by field of education
- Data on foreign new entrants and graduates by field of education
- A distinction between graduations and graduates or first-time graduates and/or data on survival/drop out rates by field of education

Besides that, there is a need for better metadata information in order to help the interpretation of the data. Some countries cannot provide data by detailed fields of science and should be encouraged to do so. Lastly but not least, any future revision of ISCED should ensure that it does not introduce new breaks in the time series at the tertiary level.

2. FIELDS TO INVESTIGATE AND ADDITIONAL RESEARCH

- need for improvement in methodology to survey students attitudes and motivations
- need for studies on best students' choice

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