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Stimulating Science and Technology in Higher Education

An international comparison
of policy measures and
their effectiveness

Rebecca Hamer, Erik Frinking, Edwin Horlings

Prepared for the Dutch Ministry of Education, Culture and Science



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Preface

This current study was undertaken for the Dutch Ministry of Education, Culture and Science, with the aim of reviewing a selection of policy measures regarding science and technology (S&T) education, and of identifying policy measures that could be successfully applied to the Dutch education system. The aim of the European Union to become the world's leading competitive and dynamic knowledge economy, as agreed in Lisbon in 2000, is directly linked to the initiative for this study. The current outflow of S&T graduates in the Netherlands is among the lowest in Europe and this is perceived as a direct threat to the innovative climate in the Netherlands and to the Dutch contribution to the success of the Lisbon agreement. Through this study the Dutch government hopes to be able to learn about successful and effective policies to improve S&T education, and support the initiatives developed by industry and education.

The Dutch Ministry of Education, Culture and Science commissioned RAND Europe to perform a review of policy measures in a sample of six European countries. The sample includes countries that have proven to be successful in attracting and retaining high levels of students and professionals to S&T related fields; countries that are only now becoming aware of the issue; and countries, in common with the Netherlands which are clearly falling behind. The six countries reviewed here are Finland, Sweden, Germany, Italy, Ireland and the United Kingdom. Where appropriate, comparisons are made to the current Dutch situation, but a review of the Dutch policy measures regarding S&T in higher education is not included. Data collection was conducted between November 2003 and June 2004.

The study consists of three main parts. First, we analysed statistics concerning developments in education, particularly those, where available, on science and technology over the previous 25 years. Second, we examined structural differences and common elements in the educational systems and identified policies that complement or address these differences. Third, we assessed potential and actual bottlenecks in accessing S&T education through document analysis and expert interviews.

This report is written for policymakers with a professional interest in educational policy in general and a concern for education in S&T in specific. However, we hope that other readers with a similar interest will find the results of interest and of professional use.

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Glossary

A-level	Advanced level General Certificates of Education
AS-level	Advanced subsidiary level General Certificates of Education
BA, BSc	Bachelor (of Arts, of Science)
BaMa	Bachelor – Masters
EU	European Union
FIPSE	Fund for the Improvement of Postsecondary Education
GCE A	General Certificate of Education A-level
GCE AS	General Certificate of Education AS-level
GCSE	General Certificate of Secondary Education
GDP	Gross Domestic Product
HE	Higher Education
HOTS	Higher Order Thinking Skills
ICT	Information and Communication Technology
IT	Information Technology
LCVP	Leaving Certificate Vocational Programme
LLL	Life Long Learning
MA, Msc	Master (of Arts, of Science)
NRC	National Resource Centre
OECD	Organisation of Economic Cooperation and Development
O-level	Ordinary level General Certificates of Education
PE	Primary Education
PISA	Programme for International Student Assessment
PSETW	Promoting Science Engineering and Technology for Women Unit
R&D	Research and Development
S&T; SET	Science and Technology
SAS	Science Ambassador
SCY	Science Community Year
SE	Secondary Education
SETNET	Science Engineering Technology Mathematics Network
SOLO-taxonomy	Structure of Observed Learning Outcomes
TEK	Finnish Organisation of Engineers
TIMSS	Trends in International Mathematics and Science Study
TLR	Teaching Learning Regime
UK	United Kingdom
WISE	Women into Science and Engineering

Summary

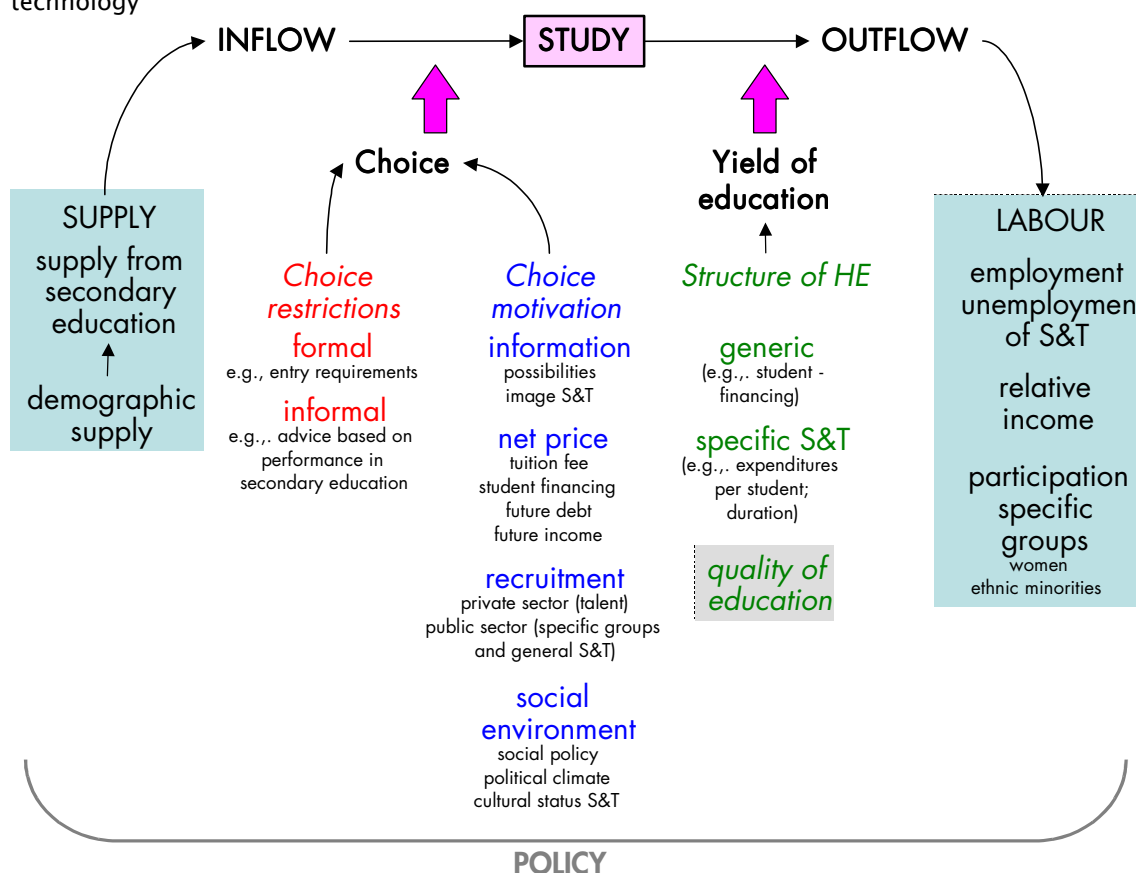
The long-term goal for Europe to become the world's leading competitive and dynamic knowledge economy was formulated at the Lisbon summit in 2000, and affirmed and specified in more detail in the following Barcelona summit. However, there is an increasing shortage of scientists in Europe, and surveys indicate that science and technology (S&T) as a career is steadily losing its attraction. The Netherlands is concerned about its low number of graduates in S&T, a weakness that is aggravated by the low female participation in S&T.

In light of this, the Dutch Ministry of Education, Culture and Science commissioned RAND Europe to perform a review of policy measures implemented in a small sample of six comparable European countries, in order to '*identify effective policy measures that can increase the uptake and pursuit of science and technology in higher education*'. This study was consequently undertaken to identify policy measures that could be successfully implemented in or modified to the Dutch education system.

The countries in this review include countries that have proven to be successful in attracting and retaining high levels of students and professionals to S&T related fields, countries that are only now becoming aware of the issue as well as countries in common with the Netherlands that are clearly falling behind. The six countries reviewed here are Finland, Sweden, Germany, Italy, Ireland and the United Kingdom.

The results presented here are based on a structured and thorough analysis of the factors determining study choice and factors sustaining the (study and career) choices made. In addition to providing detailed statistical evidence to support the findings, the study includes a review of literature on mostly psychological studies with regard to S&T education that aims to provide insight into causal relationships between policy measures and their effects and help establish the effectiveness of policies and initiatives. The analysis addresses the issues covering the whole spectrum from supply and inflow of students, choice restrictions and motivations, the structure of the various educational systems, yield and student retention and labour market issues (Figure S-1).

Figure S-1
Conceptual framework with regard to factors influencing inflow and outflow of science and technology



RAND MG270 S.1

Establishing the background regarding S&T in education since 1980

There seems to be a straightforward influence of education structure on overall S&T status. In those countries where science subjects are an explicit part of the compulsory curriculum (such as Sweden, UK and more recently Ireland), the uptake of these subjects is relatively high. In all countries, one can establish a clear gender gap, with often overwhelming male domination in engineering and the ‘harder’ technological subjects. This is even more remarkable given the gender shift in the student population as a whole. In higher education, women have caught up and now participate at least as much if not more than men. Other developments in the student population are increased participation of mature students (Sweden, UK and Germany) – which in some countries is offset by an increased inflow of young secondary education graduates (Ireland) – and the rise of ethnic groups into higher education (discussion in Appendix A)¹.

Benchmarking the student population in 2001 shows that international differences in the number of freshmen students in S&T are mainly the result of a choice between S&T and other subjects rather than a reflection of differences in the total number of students in higher education as such. The relative size of the entrants group is comparable for Germany, Italy and Finland, but in Finland a far greater portion prefer S&T over other subjects. In the Netherlands and Italy, freshmen clearly prefer law, economics, and social and health sciences. The Netherlands score particularly low on natural sciences, while its position with regard to engineering and technology

¹ Given the fact that ethnicity is not widely registered, this trend is based on anecdotal information or limited sources.

is less extreme. In Finland and Sweden, where higher education is seen as a right and therefore knows very few access restrictions, the student stock is larger than in the other countries, where it is not an automatic right. These two countries also have much larger shares of engineering and technology students per 1,000 population (age group 20–29). While Germany, Italy and Finland have fewer graduates overall than the other countries, Finland has about as many S&T graduates as the four countries with more graduates overall, indicating that in Finland the choice for S&T has been at the expense of law, social sciences etc. In all countries student retention in S&T is less (higher drop-out) than in other subjects. Only in the Netherlands is the drop-out rate of non-S&T subjects for males remarkably high, indicating perhaps shifts in tertiary education (e.g. between formal and other forms of education) that are not captured by these statistics.

A long-term perspective gives rise to an increased urgency for initiatives to turn around some developments in some countries. Comparing the growth rates of student populations between 1990–2000 shows that

- the number of men pursuing technology/engineering subjects has been on the decline for over 10 years,
- in Italy and the Netherlands the male student population has declined across the board,
- in Sweden and Finland (for S&T) and the UK and Ireland (in particular the science studies) the student population is characterized by rapid growth, both for men and women,
- the decline in freshmen S&T students dates from the late 1980s in Germany and Italy, starting some 10 years later in the Netherlands; only in Finland has there been a steady increase in the share of S&T,
- while Finland has been able to capitalize on developments resulting in a steady rise of the S&T share, even given the decline in the last 20 years, Germany still has a share of S&T students that is only slightly below; the S&T share in Italy and Ireland is very slowly moving downwards; the Netherlands deserve to be labelled ‘falling behind’ with consistently the lowest share of S&T in the group,
- the Netherlands, and to a lesser extent Germany, have the lowest female participation in S&T.

The **employment** outlook for S&T graduates is relatively good, with significantly lower unemployment rates than in other fields. However, although unemployment for male S&T graduates is declining, female graduates are more likely to become unemployed than male graduates. The little data available on income suggests that skilled S&T graduates start out on a higher salary level (Italy, Finland, Ireland), except in teaching and publicly financed research (UK, Ireland, Netherlands). The career outlook differs between countries, with education systems leading to generally well-defined career paths (Germany, Italy and to a lesser extent Finland and Sweden) or systems leaving a broader choice for career development (UK, Ireland and the Netherlands). The demand for skilled professionals has increased over the decades and can be met by a number of countries (Finland, Sweden, Italy, UK) but there is still concern regarding the ability to match future demand.

In an effort to establish how different education systems affect the uptake of S&T, this study shows that there are large similarities in – and clear differences between – the **structure** of the educational systems for primary and secondary education. Similarities include: the general compulsory period (4–16 years); upper and lower cycles in secondary education; and moments of choice for specialisation etc. While secondary education includes at least a number of science subjects, there are differences in the explicit emphasis given to science (and technology) at primary level, with Germany, Sweden, Finland, UK and the Netherlands choosing a compulsory

approach. The emphasis on S&T in primary and secondary education is reflected in the results in international comparisons. In all countries there are two or more moments of choice for or against S&T:

1. at 12-13 in Italy (and in the other countries when choosing specialized – or lower vocational – education),
2. at 15-16 (not in Italy) moving from lower to upper cycle in secondary education and
3. at 18-19 on entering higher education or polytechnic.

In general, 15/16 seems to be the watershed age with regard to choosing an S&T-oriented study path. Although in this study no direct statistical relationship can be established between the emphasis on S&T before this age and study choice in higher education, influencing the experience of S&T before this moment would seem essential to counter the outflow at this point. Finland, Ireland and the UK have implemented specific curriculum reforms aimed at improving the image of S&T before this choice-moment with positive results. Improving S&T education through specialisation (UK) or a more practical orientation (Ireland) or including a ‘remedial’ year to improve S&T skills (Sweden) are all proven methods to counter outflow from S&T before higher education.

Access to higher education and student retention in S&T disciplines, are influenced by entry requirements, financial issues, and the quality and image of S&T.

Entry requirements: Access to higher education is either defined by the results in secondary school (A-levels in the UK, final grades in Ireland, passing grades in appropriate subjects for Sweden, Germany and the Netherlands), or entrance exams (state exam in Italy, entrance exams in Finland and the UK for Oxbridge only). In addition there are countries that facilitate alternative routes into higher education (and S&T), e.g. Ireland, Finland.

Financing: Depending on a country’s philosophy on higher education provision, countries either do not charge tuition fees for full-time state education (Finland, Sweden), or they do and fees can differ by nationality of student (Netherlands, UK), institute (UK and Italy) or type of course (UK). Various countries provide a financial system to encourage enrolment; Finland and Sweden (and Netherlands for a limited time) provide all students with grants for living expenses, while other countries limit the loans and grant system to specific groups, often depending on income (Italy) or hardship (Germany, UK).

Table S-1

An assessment of performance in six areas

	choice SE amendable	quality*	alternative routes to HE	S&T image	T/S ratio in HE	Estimated yield
Finland	++	++	++	++	-	-
Germany	-	±	+	--	+	+
Ireland	++	+	+	++	-	
Italy	-	--	-	+	--	
Sweden	++	+	++	+	++	-
UK	+	++	+	+	-	
Netherlands	±	+.+.b	++	±	+	-

Note: A plus or minus does not imply an increase or decrease in numbers or a low or high score in absolute terms. Instead, a plus indicates relative good performance within this sample of countries and a minus indicates relative bad performance.

*) source: www.pisa.oecd.org/knowledge/chap3/f3_2.htm; b) source: TIMMS 1996

Quality and image: The image of S&T is considered a major problem in attracting S&T students to higher education, such as in Germany and the Netherlands. However, even in countries with a good S&T image (UK and Ireland) there is concern about meeting the future demand of S&T professionals. While the effect of early experience with science subjects is difficult to assess, it may be reflected in a positive attitude in society towards S&T.

Ranking the countries with regard to the structure and issues that influence S&T choice (Table S-3) shows that the Scandinavian countries are the better performers, Germany and Italy perform below average and Ireland, the UK and the Netherlands occupy the middle ground in this comparison.

How and why policy measures seem to work

In an effort to assess the most potentially effective measures, RAND Europe performed a focused literature review with the aim of comparing the specific elements addressed in actual policy and various issues and elements that have been identified in the scientific and empirical literature as crucial to attract student to (S&T) education. We have focused on four common bottlenecks:

1. cultural and attitudinal aspects (including gender perspectives);
2. issues of quality of education and teaching;
3. conditions influencing student retention; and
4. labour market perspectives.

While the first two bottlenecks influence student choice, the latter two involve sustaining the choice made.

Attitudes towards S&T are not necessarily culturally fixed and unchangeable. Attitudes are influenced by awareness of and knowledge about issues. We have observed that a major part of the effort is aimed at increasing **awareness**, focusing on one or more of the following dimensions: awareness of

1. S&T as a field of study;
2. variations within S&T at higher levels where the emergence of specialties or cross-over disciplines complicate making the optimal choice and thus influences student retention;
3. future options and the attraction of potential students through awareness of the range of professions or the requirements for the profession choice;
4. career opportunities and optimizing the dynamics of the labour market; and finally
5. the influence of S&T on society and every-day life, where both the media attention and the prevalence of high profile champions or active local industries can draw attention to S&T, focus the general attention, keep the discussion going and keep developments in the public eye.

Gender-related attitudes have proven to be fairly persistent, and efforts to change these are requiring even more perseverance and patience than changing attitudes based on awareness. There are a number of behavioural issues and dynamics that interact to undermine the effectiveness of policy, in particular in a co-educational system such as

1. teacher-to-pupil behaviour where teachers differ in their treatment of pupils and students by gender;
2. perception of performance which is not gender defined, but strongly related to gender;
 1. gender group dynamics;
3. gender one-on-one dynamics where peer pressure and differences in social interactions can discourage girls from choosing S&T; and

4. gender differences and perceptions with regard to many aspects of learning. It is remarkable that none of the policy initiatives we analysed explicitly addresses any of these issues. Indeed the surprise expressed at some unexpected results seems to indicate that perhaps these behavioural issues are relatively unknown within the community of policymakers. As mentioned before, attitudes are notoriously slow to change, which implies that such policy efforts would require a sustained effort over decades rather than years.

Then there is the issue of defining the scope of policy measures. Answering the question, ‘**Whose attitudes need to change?**’ should help establish this. Within this study we have focused on five specific target populations: (1) teachers, (2) students and pupils, (3) parents, (4) employers, and (5) society as a whole. The policy measures in this review focus mostly on teachers and pupils, which may be a result of the selection in earlier stages in the study. However even with this complication it is clear that both Finland and the UK are most active in this regard, and both countries have recognized the need for long-term thinking and implementation here. The UK is unique in its ‘shot gun’ approach, developing a wide range of policy initiatives aimed at the full range of target populations. Each initiative builds on previous experiences, but emphasizes a particular niche in the ‘changing attitude’ market with clear positive results for female participation in S&T. Perhaps the effort to counter the decline in male enrolment might benefit from the insights gained here. Another remarkable result is that despite the substantial and long-term effort, Finland has not been able to increase female participation in any significant way. This may imply that a sustained effort is required to keep female participation at the level it is at this time (around 35%) – emphasising again that increasing female participation is a difficult issue requiring sustained commitment to policy targets.

Improving teaching (and S&T education in particular) is a recurrent theme in documents and policy initiatives. However, there is no clear description of what is perceived to embody **high-quality learning**. In this study we have focused on the assumption that education means emphasizing ‘learning to think’ above ‘knowing a lot’, and that higher education aims to foster ‘higher order thinking skills’ (or HOTS). This means that high-quality learning *can* be implemented from primary school upwards, but *cannot* be realized without taking a number of important issues into account. All these issues, if not addressed and not ‘built into’ the policy development, will obstruct – if not prevent – any real change or improvement taking place. These issues are (1) the teachers’ perceptions and beliefs regarding teaching and teaching practices; (2) the teachers’ level of expertise, both in teaching skills as subject expertise; (3) learners’ perceptions of learning and teaching; (4) the effect of the educational organisation on the teaching environment – in particular the issue of assigning the responsibility for good performance; (5) the effect of the origin of innovation on the level of support to implement it; (6) the combined effect of, on the one hand, teachers’ and learners’ perspectives on learning and, on the other, teaching on the learning environment and lastly (7) the effect of the learning environment on the learning outcome. In this chapter we have explicitly included issues on personal epistemology and development because we feel that in policymaking these issues are recognized as interesting in a theoretical sense, while the practical implications in education are severely underestimated. Conflicting – or even incompatible – beliefs about what ‘good teaching’ and ‘high-quality learning’ are will lead to miscommunication, resulting in less than optimal implementations, creating a sub-optimal learning environment and undermining the success of any innovation aimed at improving education. While not all these issues are explicitly included in the policy descriptions we have reviewed, we have given the benefit of the doubt to the many initiatives that show awareness of them. Under this assumption we see again that the front-runners Finland and the UK address almost the full range of issues listed here.

There are many factors influencing **student retention**, many of which are essential in the early years (first and second year) and some build up in importance over the study period. In this study we discuss the following five:

- environment: the change from a relatively protected environment to the campus society can be difficult, and initiatives creating a learning community help freshmen students to adapt;
- choice: the more students feel committed to (or feel a relationship with) the subject and the more they have a realistic view of the study and professional life thereafter, the lower the drop-out. Initiatives aimed at providing good information in this regard, help prevent sub-optimal choices and lead to lower drop-out;
- skills: as with climate, students not only need learning skills, but also life skills to function in the new environment. Initiatives aimed at improving life skills as well as study skills help freshmen students survive the first years and lead to lower drop-out and often better attainment in the long run as well;
- learning environment: when learning is less controlling, student-centred, or performance-centred will improve motivation thus in turn driving student retention;
- financial issues: while study choice is not predominantly influenced by cost considerations, financial hardship is a serious threat to student retention and many countries include specific measures to prevent drop-out for this reason.

Again Finland and the UK have the most comprehensive set of initiatives, while the other countries only address one or two of the issues above.

The efficiency and dynamics of the **labour market** for S&T graduates and professionals are not the responsibility of government alone; employers and education need to take initiatives and in fact, in many countries they are actively involved. Government policy measures address the following five bottlenecks:

- insufficient outflow of S&T graduates from higher education: this outflow is influenced by insufficient uptake of S&T as a study choice. Measures that focus on improving this uptake assume that S&T students will proceed into an S&T-related career. However, there is also evidence that graduates from near-S&T disciplines can and do flow into certain S&T career paths. Most policy measures do not address this latter issue but concentrate on influencing study choice earlier in the supply chain;
- outflow of S&T graduates and professionals into non-S&T careers: while a proportion of the outflow is due to personal motivations, policy can influence this outflow by providing sufficient and attractive post-graduate or post-doctorate positions and improving working conditions and salaries. There are a number of policies in the review, which address this issue successfully. In addition, there are a few policies aimed at providing incentives to industry (or education) to provide for S&T-oriented positions. However, we feel that an overall long-term view is missing at this time;
- outflow of S&T graduates and professional to other countries (brain drain): while a proportion of the ex-pat professionals may in time return, the motives to remain abroad often touch on the excellence of the institutes there. In addressing this issue European governments should consider establishing similar centres of excellence throughout Europe;
- import of (foreign) professionals to meet demand: four countries in this review have developed policies to attract) professionals or provide incentives for remigration of

nationals working abroad. Implementation is not without problems and results are unclear.

Pulling all the previous results together, we have been able to establish **which policy measures made a difference**. Despite the shortage of valuable evaluations, we feel that there are a number of reports that hint at the positive impact of certain policy initiatives. The existing data seems to indicate that

- S&T enrolment is positively influenced by measures aimed at
 - creating a second chance to choose S&T or to rectify insufficiencies in S&T skills;
 - offering more practice-oriented curriculum and vocational options;
 - improving the S&T skills of teachers in SE and HE;
 - providing information (access) with regard to career options in S&T, supported by mentoring and role models;
 - specialisation within disciplines;
- Pursuit of an S&T career is positively influenced by measures aimed at
 - more efficient match between labour market needs and S&T supply;
 - creation of research fellowships, post-doctorates and R&D in industry;
 - improvement of salaries and stipends;
- Simplifying immigration procedures and offering financial incentives are successful in attracting foreign or ex-pat scientists and professionals to meet current demand.

In summary: the observed countries have quite different levels of performance regarding policy development and S&T uptake and have been confronted with quite different structural problems, which leads to differing views on urgency and priority of issues. Roughly speaking, one can discern three groups of countries:

- those dealing with employment issues and later stages of higher education;
- those having problems in the early stages of higher education compounded by demographic developments; and
- experiencing considerable (relative) drops in S&T enrolment, in particular for male students, and where the supply of skilled teachers is a policy priority.

What are the major lessons to be learned from this study?

1. The complexity of the issue and the underlying causal dynamics require a comprehensive approach

Given the important impact of culture and tradition on choice behaviour, it has been stressed in evaluation reports and feedback from stakeholders that a broad range of policy measures is required to affect the overall volume of the supply of S&T researchers. Stakeholders in the various countries have indicated that the focus of policymakers should not be on individual measures. Countries that are currently being perceived by other countries as successful have either implemented their comprehensive programmes more than two decades ago and/or already had relatively high levels of S&T students and researchers.

2. This type of change requires a long-term perspective and long-term commitment of resources

Changing beliefs and perceptions of individuals is difficult. All the evidence indicates that when these beliefs are not made explicit, and are made an object of reflection, beliefs and perceptions are particularly resistant to change. This means that policymakers should be more aware of these beliefs and perceptions, and take the effort of changing them into account when devising policy.

3. To identify effective policies, it is necessary to emphasise the need for evaluations based on measuring effectiveness

The concept of 'evidence-based' policy has only emerged in recent years, and is accompanied by a growth in the demand for performance measurement and policy audits. This study has also shown that the effectiveness of individual policy measures is difficult to measure. The scarcity of data on the effectiveness of policies is a serious obstacle to policy analysis and policymakers should include provisions and requirements to facilitate such evaluations in the future.

4. Gender balance in all S&T disciplines should be a long-term objective, and the gender ratio may be extremely resistant to change

Women are often perceived to be a largely untapped resource for S&T workers, which only requires sufficient 'indoctrination' to unlock the considerable supply. There is sufficient evidence that women can and do perform as well as men in S&T, and often do particularly well in a non-co-educational system. However, many might simply be more interested in other subjects. The persistence of traditional choice behaviour, possibly due to gender differences, would perhaps indicate that aiming for equal representation in each and every one of the S&T disciplines may prove to be unattainable – at least in the intermediate and perhaps even in the long term.

5. Alternative routes and flexibility of curriculum can help prevent an early lock-out of potential S&T students

There seem to be differences of opinion in whether choices for S&T should be fixed early in education (i.e., in the transition between lower and upper secondary education) or later on just before or in tertiary education. Introducing transition or preparatory years between secondary and tertiary education (potentially followed by entrance exams) have been instrumental in changing or focusing choice behaviour toward S&T subjects. Also, the possibility of entrance to S&T studies in tertiary education through vocational education seem to have positively affected the entrance of additional numbers of S&T students. However, the overall volume of these alternative routes is in general relatively small. Therefore the overall impact on S&T ratios might be marginal although may still be worthwhile to help boost these ratios in the desired direction.

6. The quality of teachers and of teaching practices should be improved, specifically in secondary education

Improving the quality of teachers specifically in S&T-related subjects has been a widely embraced policy that has positively affected the attraction of S&T especially in secondary education. Without sufficiently qualified teachers, students will lack the necessary incentive to follow S&T-related studies. Improving quality should not only be interpreted as improving specific teaching skills. High-quality teaching often requires teachers, students and organisations to examine their perceptions and beliefs about teaching and teaching practice. All stakeholders in the teaching-learning process will need to reflect on their beliefs and learn how to change. Policymakers should take this into account when designing new educational policies and provide incentives to facilitate this reflection.

7. The engagement of industry in showing the attractiveness of S&T is essential

We have seen many different ways in which industry (or otherwise privately initiated S&T) can be instrumental in developing more attractive career opportunities and perspectives of work in S&T than is currently offered. These ways can be grouped in various approaches:

- Involve industry in promotion to highlight attractive career opportunities;
- Involve industry in determining what longer-term skills might be required;
- Involve industry in offering programmes of work experience to provide hands-on experience in S&T-related professions.

Acknowledgements

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The resulting product is the sole responsibility of the authors.

Background and research questions

Science and technology uptake in Europe

In March 2000, the European summit in Lisbon resulted in the formulation and acceptance of an important long-term strategic goal: Europe is to become the world's leading competitive and dynamic knowledge economy. During the following Barcelona summit this strategy was specified in more detail, calling for a doubling of expenditure in private and public research within eight years. The grand total of R&D investments in 2010 should comprise 3% of the GDP.² In March 2003, during an intermediate European summit in Brussels this 3% target was reaffirmed and the member states were urged to take all necessary steps to ensure that it would be met.

Policymakers in Europe as a whole, and the European Union in particular, admit that to create this competitive and dynamic knowledge economy it is important to increase the innovation potential of the European economy. Stimulating the supply of innovative products, processes and services through increased R&D expenditures is only one side of the issue. It is essential to scrutinize the supply of appropriate workers to the innovation market as well. The EU member states realise that there is an increasing shortage of scientists in Europe. Furthermore, various surveys indicate that within Europe, pursuing education and a career in science and technology (S&T) is considered less attractive and the attraction is decreasing steadily over the years. This decline in the image of S&T is partly due to insufficient public investments in research staff, facilities and work.

Consequently, following the summit in Brussels, the European Commissioner for Research, Philippe Busquin indicated that it is crucial to increase public and private investments in research as well as increasing the number of scientists working in Europe by 70,000.³ To be able to attain the targets set, the EU will need to secure the necessary numbers of highly educated and skilled research personnel within its borders. In order to do this, the Commission formulated plans to increase the attractiveness of S&T as a discipline and as career.⁴ These plans include improving work conditions, encouraging interaction between universities and the private sector, as well as funding research positions (e.g., through the Marie Curie Programme).

Obviously, the supply of research professionals depends on the pool of graduates from relevant educational disciplines. The expected potential shortage of researchers will certainly occur, notwithstanding the fact that the number of S&T graduates in Europe is on average higher than in North America, Japan and South East Asia.⁵ However, this is no reason to be overly optimistic. The number of graduates for mathematics, physics and chemistry has been rapidly declining, in

² COM(2002) 499 final, Brussels, 11.9.2002. It is indicated that 2/3rd of the 3% (i.e. 2% of GDP) should comprise private expenditures in R&D and 1/3rd from public investments (i.e. 1% of GDP).

³ COM(2003) 226 final of 30.04.2003

⁴ COM(2003) 436 final, Brussels, July 2003

⁵ OECD, Education at a Glance, 2003

some countries by more than 30% over the past decade.⁶ On the other hand, there is a positive growth in the number of graduates in ‘new’ S&T disciplines, such as biology, biotechnology and information science, as well as initiatives within the informal educational system (e.g. ICT-qualifications through Life Long Learning programmes (LLL)). It is clear that many countries have been encouraged by the targets set at the European level and are now searching for solutions to meet them. Increasing the attractiveness of S&T is a major priority.

Importance of S&T for the Netherlands

The Netherlands aims to be at the forefront of Europe on all three policy goals mentioned above. Dutch public investments in research are currently not an obstacle in meeting the objectives. On the contrary, the Netherlands is one of the EU-countries with the highest public expenditure and has almost attained the 1% goal. However, the private research expenditures are less on track and the Dutch situation with regard to the proportion of R&D personnel (10.9 per 1,000 employees) and the number of researchers (5.2 per 1,000 employees) is less than aimed for. Even so, the Dutch situation is near or somewhat better than the EU average for these indicators (10.6 and 5.6 respectively).⁷

However, the low number of graduates in S&T disciplines in the Netherlands is a major issue of concern. It seems that this is the Achilles heel of the Dutch innovation system. In comparison with most European and non-European OECD countries the proportion of graduates in S&T in relevant age groups as well as in the total student population is very small. The Netherlands is at the low end, leaving only countries such as Luxembourg, Malta and Cyprus behind. A striking additional weakness for the Dutch situation is the low participation of women in S&T.

In the past, the Dutch government has initiated a number of programmes aimed at making S&T education more attractive. These information campaigns were aimed at secondary education (‘Kies exact’) as well as at higher education itself. Furthermore it has initiated curriculum reform to include a compulsory S&T-related subject (‘natuur en techniek’ [natural science and technology]) in the lower secondary cycle. Evaluation of the information campaigns showed that they were less than effective, while the pressures to decrease the study burden in the secondary cycles has led to cuts in the curriculum in particular at the expense of new subjects such as ‘natuur en techniek’.

In order to increase the inflow of students into S&T, the government established the Axis Platform for Science and Technology in the Netherlands in 1998. Axis is the national platform for education and employment in the natural sciences and technology, initially created for a period of four years. It is a cooperation between industry, government and the educational sector to co-finance unorthodox projects aimed at maximizing the participation of pupils, students and teachers in S&T subjects. The target includes the educational system as a whole – from primary to higher technical – as well as industry. The three main goals are:

1. Stimulating more project-oriented initiatives aimed at increasing the attractiveness and effectiveness of technical and physical science education;
2. Promoting research and evaluation to improve understanding of the decreasing attraction;
3. Communicating activities and results at national and regional levels.

⁶ Benchmarking National R&D Policies, Human Resources in RTD, Strata-Etan expert working group, Final report, 21.08.02

⁷ Main Science and Technology Indicators, Volume 2003/1, OECD, 2003

Although the current Dutch situation is perceived as far from ideal, other European countries face similar problems regarding inflow and outflow of S&T graduates, albeit in different magnitudes. Possible solutions to the lagging uptake of S&T lie in a variety of directions. In many countries in Europe these directions have been explored and policy measures can be described. In particular, many countries have focused on improving the quality of S&T education in secondary education as well as in (preparatory) higher education. Examples are the NOT (Sweden) and LUMA (Finland), various projects in Scandinavia, the BLK project in Germany and *The Task Force for Physical Sciences* in Ireland. These examples are discussed in detail in the remainder of this report. Therefore, there is great potential for learning from a comparison of the experiences of different countries. This report presents the results of an international comparison of societal factors and policy initiatives that influence the attraction of S&T subjects in higher education. The study focused on various stages of the education and labour lifecycle within which supply and demand for S&T can be assessed.

Research questions

The major question that underlies this study is

Is it possible to identify effective policy measures that can increase the uptake and pursuit of science and technology in higher education?

To answer this question we need to first identify the factors that influence the uptake of S&T in countries similar to the Netherlands. Second, we need to establish whether these factors can be influenced by policy and, if so, if we can identify effective policy measures.

In order to identify underlying factors, we have looked at three areas of interest:

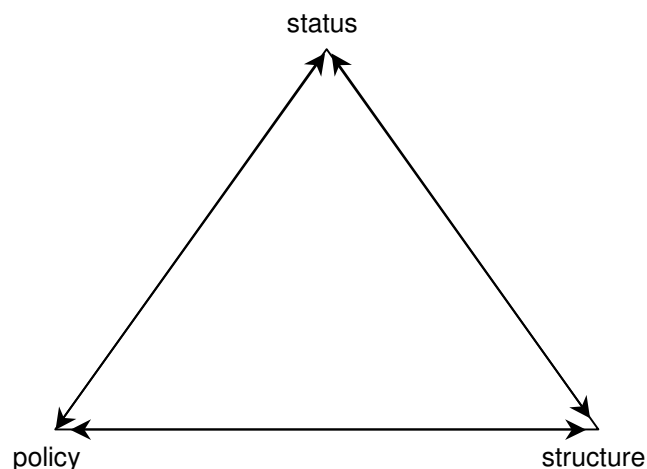
- the current status and past developments related to S&T in higher education in recent years, such as demographical characteristics of (student) populations;
- the structure of systems, such as the educational system or the labour market; and
- policy measures aimed to stimulate the uptake of S&T .

These three categories do not operate independently, but influence each other either directly or indirectly. They can be perceived as the three corners of a triangle of complex interactions and influences, as is represented by the arrows in Figure 1-1. For instance, in the past policymakers have influenced the structure of education. These policies, together with the demographic trends – such as falling birth rates or the procession of large cohorts through the population – resulted in a specific outflow of skilled and unskilled workers and so influenced the structure of the labour market.

The basis of the analysis is an international comparison in which we focus on differences between countries. The important issue here, of course, is not establishing whether differences exist, but finding out whether these differences could explain the position of a country is in with regard to the uptake of S&T education and the prevalence and prominence of S&T within the economic structure. In particular, we need to know if there are characteristics that can be identified as drivers for the level of S&T uptake in society as a whole.

Within these three broad categories we have identified a larger set of more detailed questions which are aimed at identifying issues that influence the current level of S&T uptake. The list of questions is clustered by category and given below.

Figure 1-1
Influence triangle linking the existing status to policy development and changing structures



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Questions regarding the developments in recent years

These questions focus on describing the current situation, putting it in perspective when data is available and describing the recent developments.

Cultural and economic differences

1. What is the quality of S&T education in secondary education and what are cultural attitudes towards it?
2. Do the countries differ greatly in economic prosperity, political system or average income?

Demographical descriptions

3. Are there demographical differences in the general population (with regard to age distribution, gender, ethnicity)? What are the trends here?
4. Are there demographical differences in the general student population (with regard to age distribution, gender, ethnicity)? What are the trends here?
5. Are there demographical differences in the student population for science, engineering and technology in higher education (with regard to age distribution, gender, ethnicity)? What are the trends here?

Labour market

6. What is the level of employment for higher-education graduates, and how is this for S&T graduates?
7. What is the career and income development for S&T related occupations? Does it differ from the expectations for other (non-SET related) careers?
8. Has the demand for skilled professionals changed over the last decade? Is the supply of indigenous skilled professionals in general and within S&T in particular, sufficient to meet the current demand?

Questions regarding the structure of systems

Secondary education

1. Is the uptake of S&T education influenced by the structure of secondary education?
2. At what age do pupils make a more or less definite choice regarding major subjects (including S&T subjects)? Are there ways to change or amend this choice later?

3. Can the differences in S&T uptake between groups, in particular regarding gender, be explained?

Higher education

4. How is the inflow in higher education structured and to what extent is inflow from vocational education possible?
5. What is the quality of S&T education in HE and what are cultural attitudes towards it?
6. What is the duration of higher education in general and of S&T in particular?
7. Is student retention affected by the structure of higher education and of the structure within S&T?
8. Is it possible to combine S&T studies with other disciplines (i.e. through majors and minors)? To what extent does this occur and which combinations are dominant?
9. What are the possibilities to change within higher education: to shift within S&T or to shift in or out of S&T?
10. Have there been changes in the structure of higher education that have resulted in changes in the inflow and outflow of higher education, and S&T?

Student financing

11. Are there tuition fees and is there differentiation between educational institutes or disciplines?
12. To what extent are students supported by public funding and are there specific support structures for S&T?
13. Have there been significant changes in the financial support structure in the last decades and have these resulted in shifts in inflow and outflow of students with regard to S&T?

Questions regarding policy measures

These questions explore existing policy measures and where possible examine their effect on S&T.

1. Are there, or have there been, policy initiatives aimed at influencing the choice for S&T, targeting specific (demographic) groups?
2. Are there, or have there been, initiatives to encourage immigration of skilled professionals to counter labour market demand? For which type of professional?
3. Have there been initiatives to change or amend the S&T education towards student preferences and where they successful?
4. Are there or have there been initiatives to influence the choice in higher education towards S&T and were they successful?
5. Are there or have there been initiatives from industry to increase the number of S&T graduates?
6. Is there a relationship between the political or socio-cultural climate and education expenditure or allocation of means within education?
7. Is there a relationship between shifts in political or socio-cultural climate and the policies towards or uptake of S&T?

The central issue in this study remains determining if and to what extent developments can be steered using policy measures and which policy measures seem to be most effective. This issue is addressed through a literature review in chapter 7 in which we describe probable causal relations between policies and effects.

Reading this report

This report summarizes and analyses the results of an international comparison of six European countries. The approach to the study, the selection of the countries, the data collection procedure and the methodology are described in chapter 2. In the following three chapters the main results of the comparison are presented. In chapter 3 we discuss the aspects influencing the inflow into higher education and S&T in particular. Issues discussed are developments regarding demography, education and S&T uptake in secondary education. In chapter 4, we present results regarding the current uptake of S&T in higher education (new entrants) and the developments in uptake since 1980. We highlight female participation in S&T and discuss aspects of higher education that influence study choice. Chapter 5 addresses the outflow of S&T graduates in the six countries and the Netherlands, and details the labour market position of S&T graduates and professionals. In chapter 6 we discuss the various policy measures that have been implemented and their effectiveness. In chapter 7 a literature review supports the causal links between aspects of the various policy measures and their effects and effectiveness. The conclusions and recommendations are summarized in chapter 8. Appendix A contains a more detailed analysis of female participation in S&T over the years. Appendix B contains a table summarising the policy measures reviewed by country, listing a number of salient details of each.

Approach

This chapter will elaborate on the study approach and the procedures followed within the separate phases in the study. We discuss methodology, the arguments underlying the choice of case studies and the three stages of the study: data collection, analysis and synthesis.

Method

The study is based on a thorough and structured analysis of the factors determining study choice and the resulting output level in S&T in a selection of European countries – the six case studies. Whenever possible we tried to support the analysis with as much detailed statistical data as could be gathered for each of the six sample countries. This was used to describe the current status of S&T uptake in secondary and higher education as well as S&T in the labour market over the last 20 to 25 years. In particular, we looked at changes in

- uptake in education;
- choices and development of new subjects within S&T;
- gender shifts;
- labour market and career development.

Complementary to the use of statistical data, we focused on more qualitative data on policy measures and the effects in the various stages of the educational and labour market setting. We classified the policy initiatives and compared them in a structured way, simplifying the comparison between developments, policy initiatives and the effects on the position of S&T in education and labour market. Firstly we focused on clarifying the relationship between measures implemented and effect by looking at possible changes

- over time (due to increased insight in the underlying causes); and
- between countries (due to social and cultural differences).

The aspects of policy we looked at were:

- type of policy instrument (financial, facilitating, regulating)
- type of intervention (impulse or one off , incidental, structural)
- geographic orientation
- focus of intervention.

A complicating factor in this type of study is the contextual factors and factual differences between countries that may influence the effectiveness of policy measure. The most relevant differences pertain to the organisation and financing of the education system, student financing

and the structure and conditions ruling the labour market. Although these contextual factors may affect the effectiveness of particular policy measures, there is still potential to learn from other experiences, especially since many countries in Europe and elsewhere are undergoing similar problems and challenges. Vicarious learning from foreign examples (whether based on *good* or *bad practices*) should focus on:

- Gathering information on the various approaches taken: identifying policy measures implemented in the sample countries, and establishing success or failure factors.
- Evaluating the effect of these measures on S&T students and establishing which structures and actions have led to the current situation.

In performing such analyses we will need to keep certain facts inherent to international comparisons in mind:

- Comparisons of good and bad practices are always limited in some way; we are making use of descriptions that are only approximations of the real situation.
- It is impossible to control the comparison for all the possible influences, or determine what the effect of each aspect is, simply because there are too many options. While the study must provide policymakers with valid and reliable information, the analysis and conclusions should not project a false sense of absoluteness.
- The innovation system and the underlying policy area are in a state of constant change, which is influenced by many factors. Initiatives need to be designed with a certain measure of robustness to withstand this constant change.

Selection of countries

The study focuses on gathering information of the situation and policy practices in six countries with the aim of providing inspiration for changing the current Dutch situation. Where appropriate, comparisons are made to the current Dutch situation, however a review of the Dutch policy measures for S&T in higher education is not included. Before performing this study four types of countries were discerned. Based on a quick survey, these countries differ in respect to S&T uptake and were characterized as

1. **'Forging further ahead'** [high level and continuing growth]
2. **'Losing momentum'** [high level but losing momentum]
3. **'Catching up'** [low level, but increasing momentum]
4. **'Falling further behind'** [low level, and low growth]

In selecting the countries to be reviewed, we gathered information on eight indicators. This information was collected for a selection of the OECD countries and the 25 EU-countries (including the 10 New Member States). This exercise resulted in the following list of eleven countries: Finland, Sweden and Spain (forging ahead); Ireland, the United Kingdom (UK) and France (losing momentum); Italy, Austria and Poland (catching up) and Germany and the Netherlands (falling further behind).

The selection of the six case-study countries was a two-tiered procedure. In this phase the Netherlands was dropped from the list of potential case studies. The first four countries were chosen to each represent one of these categories, namely Finland, Ireland, Italy and Germany.

Table 2-1
Economic characteristics of the comparison countries, c. 2000

	per capita Gross Domestic Product (EU=100)				compound average growth of per capita GDP (%)		
	1980	1990	2000	2003	1980-1990	1990-2000	2000-2003
Finland	97	105	102	103	2.7	1.5	1.3
Sweden	109	107	105	107	1.7	1.6	1.5
Ireland	66	76	118	128	3.3	6.4	3.8
Italy	103	106	103	102	2.2	1.4	0.7
UK	93	98	101	103	2.4	2.0	1.7
Germany	110	110	105	103	1.9	1.4	0.2
<i>Netherlands</i>	<i>111</i>	<i>108</i>	<i>114</i>	<i>110</i>	<i>1.6</i>	<i>2.3</i>	<i>-0.2</i>
EU-15	100	100	100	100	1.9	1.8	1.0

Note: Germany in 1980 includes East Germany.

Sources: OECD; Groningen Growth and Development Centre and The Conference Board, Total Economy Database, February 2004, <http://www.ggdc.net>

The second set of two countries was based on a quick scan of four additional countries: Sweden, UK, France and Austria, focusing on the completeness and availability of the necessary data. The UK and Sweden were subsequently chosen to complement the six case studies.

Description of the six countries reviewed

The six selected countries are all parliamentary democracies, with governments alternating between various political parties during the last decades. These governments have all developed policies to support and improve education, with particular attention to higher education and S&T. In general there is no evidence that the priority given to education shifts greatly in light of political developments. The similarity across our survey is intentional, because it was considered necessary to select comparable countries, in order to maximise the possibility of transferring policy measures. It would not be efficient to include systems that are significantly different from the current Dutch system, then to realise that implementing the identified policy measures would require large structural changes in the Dutch political and social system.

The countries in our sample belong to the wealthier half of the EU Member States with per capita GDP higher than the EU average and, hence, to the world's highest developed economies (Table 2-1).

In terms of per capita income, Ireland has rapidly caught up with and surpassed its European competitors. On the other hand, Italy and Germany are gradually losing ground, even though their per capita GDP remains above average.

In general, the countries have experienced a similar economic development since 1980, although the recession of the 1980s affected the Netherlands and Sweden more than the others; as indicated, Ireland has experienced spectacular growth and it now has the second highest GDP per capita in the EU.⁸

⁸ Luxembourg tops the list.

Since 2000 the rate of growth has, in varying degrees, slowed down in all countries. Even at a considerably lower rate of growth, Ireland still outperforms the other EU nations. The Netherlands, Germany, and – to a lesser extent – Italy have slipped into recession. Unification makes Germany a special case: the major undertaking of bringing the ‘Neue Länder’ into the economic prosperity of the West has seriously hampered economic growth in Germany during the last 15 years. Wages in former East Germany are still lower than in the rest of the country and unemployment is higher.

This overall economic picture could, of course, be presented in much greater detail; the economic organisation in industry and services might show various strengths and weaknesses in each of the countries that could have a connection with the supply and demand of S&T students and professionals. Given our main focus on (higher) education that discussion goes beyond the scope of this study.

Data collection

The more recent statistical data as well as much of the qualitative data regarding the current status of the country, the structure of the educational system, the policy measures implemented and information on results, were collected by the analysts performing the country analysis. The search comprised of an Internet search followed up by acquiring and analyzing reference material, telephone interviews and follow-up contacts. The data on Finland was collected by our Finnish partners, the other analysts are RAND Europe staff. For the full list of material used, see the reference section of this report. Data collection took place between November 2004 and June 2004.

Analysis

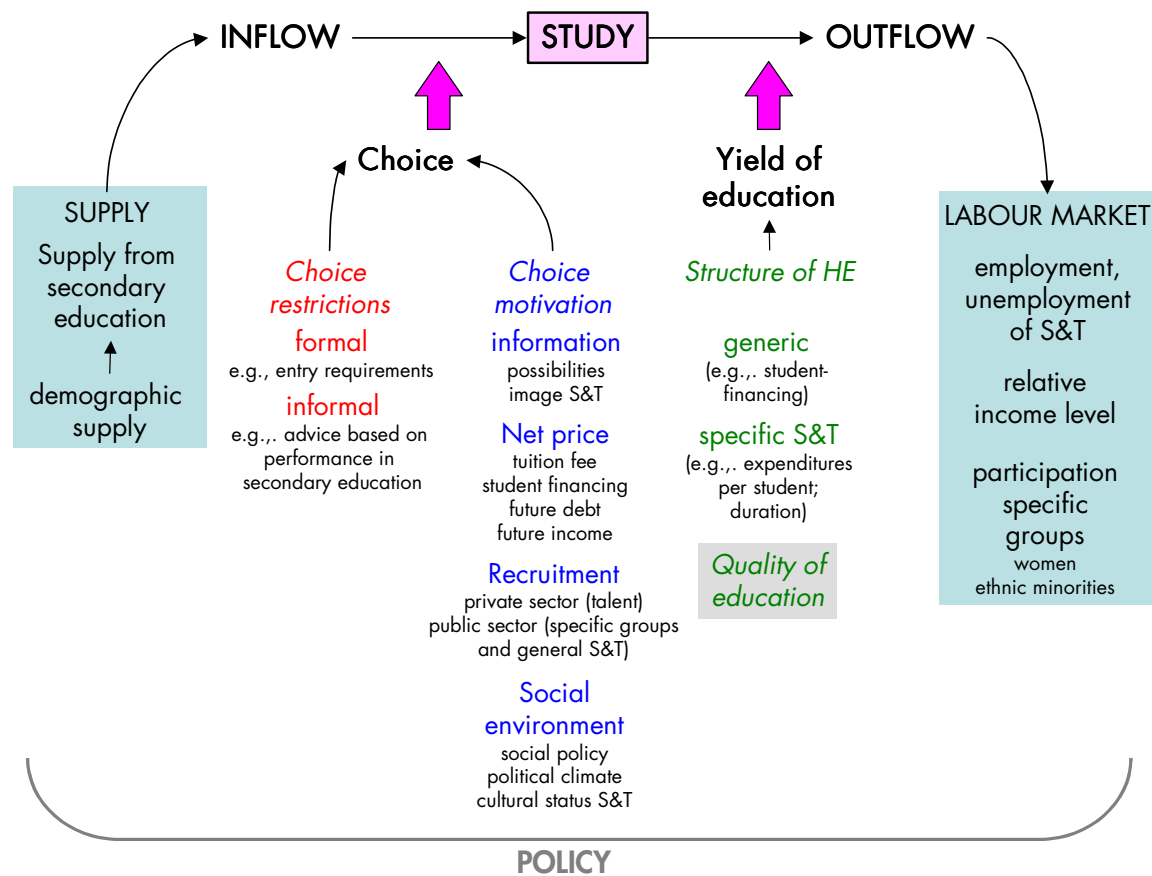
Many of the research questions formulated in chapter 1 refer to issues raised in the conceptual framework presented below (Figure 2.1).

Going from left to right, we first identify the influence of demographic trends on the composition of the outflow of secondary education (SE), only part of which becomes the inflow in higher education (HE). While the gender ratio is usually close to equal, this can be very different for certain types of education or disciplines, e.g. primary teaching and nursing is often female dominated, while engineering is often male dominated. The gender ratio can change due to policy or autonomous trends, which can have repercussions on the perception and attractiveness of a subject, career options or even on the future supply to the labour market, e.g. the gender shift towards females in the GP graduates in the Netherlands.⁹ Then demographic trends can influence the uptake through culturally determined choice behaviours.

Second, the inflow into HE – and S&T in particular – is influenced by formal and informal (or cultural) issues that affect study choice. The informal issues are captured in the questions concerning the social and cultural status of S&T in the country as a whole, perceived capabilities, based on advice and study counselling in SE, as well as image and expectations about career development and so on. The formal issues influencing choice in HE often refer to structural aspects of the educational system – i.e. entrance requirements, available learning routes, etc. – and

⁹ Recently it is proposed that this could be one of the major drivers for the growing (and future) shortage of GPs. The female GPs are less inclined to work long hours (60 to 80 hours per week) and often form associations where they can keep more regular hours (40) or even work part time.

Figure 2-1
Conceptual framework with regard to factors influencing inflow and outflow of science and technology



RAND MG270 2.1

factors that influence the choice for a subject – i.e. information access, cost and support options, study duration.

The outflow or yield of HE is a result of the quality of the educational environment and the demands it makes on the students, but can also be influenced by the structure of HE and financial issues. This means that the questions on the structure, the quality of the teaching and study financing, should give insight into the dynamics underlying student retention.

Finally, the test determining whether people will continue in S&T is in the extent to which the labour market is able to function. If the labour market for S&T is less attractive than other markets and there is sufficient demand in other areas, all efforts to increase the uptake and outflow of S&T graduates and to increase science literacy will be less than effective in increasing the proportion of researchers and improving the climate for innovation.

In the analysis we have focused on interpreting these issues in light of international cultural differences. Different factors that could be attributed to different outcomes are highlighted in the results section (chapters 3 to 6).

Synthesis

The final step in the research project focused on bringing the analyses of the different research questions together, determining:

- whether certain drivers that influence the attractiveness of S&T can be influenced by policy: and
- which policy measures seem to be most effective.

The synthesis (chapter 8) illustrates the different perspectives regarding the most obvious issues to address, and contains recommendations about these issues that need to be considered when developing different policy measures.

A perspective on supply

Following the conceptual Figure 2-1, this chapter provides an overview of the situation of factors affecting the inflow of prospective S&T students into higher education. These factors are:

1. the demographic developments in the seven countries;
2. the nature of S&T education at primary level;
3. the S&T uptake and curricula in secondary education; and
4. the female participation in S&T at secondary level.

While the first three issues are clearly and directly related to inflow into higher education as a whole, the fourth aspect can be interpreted as tapping a potentially powerful but currently underused source for increasing the uptake of S&T in higher education.

Demographic developments

The demographic development of European countries is largely similar: growth is slowing down and the population is ageing. The population share of the age group most relevant for higher education (20–29-year-olds) is roughly similar in all countries, with the exception of Ireland, which has the youngest population. Yet, even among the most highly developed countries some differences can be noticed.

Table 3-1
Demographic growth and structure in the comparison countries, 1991–2001 (%)

	average growth of total population, 1991–2001 (%)	share of 0–19 year olds in total population in 2000 (%)	share of 20–29 year olds in total population in 2000 (%)
Finland	0.3	24.6	12.2
Germany	0.2	21.2	11.6
Ireland	0.9	30.4	16.3
Italy	0.1	19.3	14.3
Sweden	0.3	24.3	12.3
UK	0.4	25.2	13.0
<i>Netherlands</i>	<i>0.6</i>	<i>24.4</i>	<i>13.2</i>

Source: US Census International Database.

In Ireland and the Netherlands, population growth is faster than in the other five countries (Table 3-1). The Irish population is relatively young, reflecting the substantial remigration of the 1970s. However, the age group below 15 is declining and the fall in the size of cohorts leaving secondary education has already produced a shortage on the labour market.¹⁰ This shortage is in part alleviated by the increase in female labour participation, but the reduction in cohort size also results in fewer S&T graduates in absolute numbers, which is an additional concern.

The future supply of students can be deduced from the population share of the youngest age groups (0–19-year-olds). This reveals that in the near future Germany and Italy will be faced with a decline in students relative to the other countries. Despite the aforementioned shortages in the labour market, Ireland still has by far the largest relative share of potential supply to higher education.

There are two sides to this issue. A high future supply of students means that the number of skilled workers will potentially grow faster than in other countries. However, it will also increase the financial burden of higher education on society. The expectation is that the additional economic growth brought about by the employment of highly skilled employees (e.g. in R&D) will generate sufficient growth to offset the resources used in their training.

Primary education

There are most certainly differences across the countries considered in this study. However, there are also common characteristics. In all countries included, education is mandatory up to approximately 16 years and comprises a primary education (up to 12 or 13) and lower secondary education. However, the countries differ considerably in the manner in which S&T is included at primary and secondary level.¹¹

While S&T at the primary level of education (up to the age of 12) is not a specific focus of this study, it has been argued that S&T-oriented education in this age category can help stimulate the later uptake of S&T in secondary and tertiary education. Two hypotheses highlight the potential importance of S&T in primary education:

- the focus on S&T in primary education is a reflection of (increased) socio-cultural attention to these issues (and thus is reflected by a larger share of S&T in later stages of education as well).
- the focus on S&T provides a basis for greater interest in S&T-related issues in later stages and creates more incentives for the take-up of S&T when specific choices are provided.

We have examined the basic provision of S&T on the primary levels in each of the countries surveyed. Given the restricted possibilities or desirability to create specific educational programmes under the age of 12, the variance of experiences across countries is limited. Thus, we have been able to divide our sample countries into two broad groups.

S&T is not a priority in Italy and Ireland. Until recently, the Italian and Irish primary education systems did not have a specific focus on S&T subjects. Despite its not very proactive stance on S&T, Italy has recently invested heavily in improving computer availability at schools, in part to introduce more science-related subjects at this level. For many years Ireland had no national policy on science education, resulting in large numbers of primary and secondary schools

¹⁰ <http://www.ilo.org/public/english/employment/strat/download/etp44.pdf>

¹¹ The various regions within the UK have different educational systems. When referring to the UK, we primarily discuss the system in England and Wales.

not offering any explicit science education at all, or only one or two subjects. This meant that for large numbers of pupils their first experience of science came relatively late. However, Ireland has developed major curriculum changes for all levels of education, introducing more emphasis on S&T subjects.

S&T is compulsory in Germany, Sweden, Finland and the UK. These countries are similar to the Netherlands, with compulsory science subjects at primary and secondary levels. School children in Germany are exposed to science at an early age, although the intensity remains relatively low throughout lower secondary school. There are no national standards as far as content is concerned. Sweden has national standards that require passing grades in mathematics (as well as in Swedish and English) to have access to upper secondary school. Even so, a review in the 1990s showed that the understanding of science at primary level was poor, which led to a political priority on science teaching and teacher training. In the UK all children between 5 and 16 receive a balanced science education, including mathematics, biology, physics, chemistry as well as aspects of earth science and astronomy (OECD, 1997). Finland is exceptional in its emphasis on S&T at all educational levels, and pupils perform very well in international comparisons regarding science literacy.

Whatever the emphasis on or the inclusion of S&T in the curriculum of primary education, the effects that it has on S&T in higher education are difficult to verify. Although the loss or outflow of S&T potential might or might not be mentally initiated at this stage, in a structural sense no specific groups of students tend to be excluded.

There is reason to think that the Finnish situation reflects the first hypothesis formulated in the beginning of the section: the focus on S&T is a reflection of its status within Finnish society. The share of S&T students in higher education remains at a high level. To a lesser extent the same applies to Sweden. However, there does not seem to be clear support for the second hypothesis based on the practices in the six countries covered. 'Low attention' countries, such as Italy and Ireland, position themselves right in between the other surveyed countries that have presumably more focus on S&T in primary education.

Secondary education

While primary education might indirectly influence choice behaviour in later stages, secondary education incorporates the structural apparatus which can directly influence the choice for S&T in higher education. First of all, many secondary education systems provide one or more moments of choice for S&T-related subjects, which may or may not be irrevocable, depending on the age at which they are made. In this respect, the choices made before 16 years of age (and thus, in most countries, during mandatory education) should be separated from choice-moments after this age.

In five of the seven countries and the Netherlands, secondary education is organized in two cycles, lower (or junior, up to about 15) and upper (or senior for 16 and over). Education in the junior cycle is compulsory and often gives access to vocational further education. The transfer from the junior cycle to the senior cycle is often also the moment to choose for more specialized science courses giving access to S&T in higher education, or to opt out (Table 3-2).

Second, the depth and breadth of the curriculum provided can vary considerably. This can lock in the choice for S&T to a various extent. For example, an early in depth S&T curriculum might be a prerequisite for further options in S&T. If the curriculum is broader, the choice for a more specific S&T education will be made later during secondary education.

Table 3-2

Overview of moments and direction of choice for S&T in secondary education for the various countries surveyed

	Before 16	16 or later
Finland	Balanced science curriculum	Short or extensive maths courses Voluntary natural science courses
Germany	Mandatory science inclusion	Specialized science profiles
Ireland		Leaving certificate science
Italy	<i>Liceo scientifico</i>	<i>Liceo scientifico</i>
Sweden	Diversified national programmes	Diversified national programmes
United Kingdom	Balanced science curriculum	A-levels
Netherlands	<i>Balanced science curriculum</i>	<i>Basic maths compulsory, voluntary courses in sciences and advanced maths</i>

The face of S&T

The watershed for making a choice for S&T during secondary education tends to come at 15–16. As alternative routes to S&T in higher education are not common and often take additional effort, influencing the choice behaviour by this point would seem essential. We have divided the circumstances that are most favourable to encourage students to choose S&T at this age into three groups.

S&T has its own place and a face (Finland, Ireland and Sweden): Finland is the ultimate example, with many years of policy development (starting in the 1970s) aimed at improving science education and uptake on all levels. The choice is basically done at the age of 16 when the student enters the upper secondary school. However, it is also possible to choose S&T later, by completing extensive mathematics courses separately or by attending extra courses at university. At upper secondary school (starting at age 16), students select either short or extensive courses on mathematics and select voluntary courses on natural sciences (physics, chemistry). A precondition for access to most S&T studies in higher education is that the student has taken extensive courses in mathematics. Also, the voluntary courses on natural sciences increase the chances of students to get into university.

In Ireland, Second-level education consists of a three-year junior cycle followed by a two- or three-year senior cycle. In secondary school about 90% of students do science up to the junior certificate. Almost all students on the secondary education level follow one or more science-related courses up to Junior Certificates. Junior certificates give access to vocational education. Senior cycle courses result in Leaving Certificates, which allow access to higher education. For S&T, they are perceived as difficult and demanding. Thus, science at higher levels has a somewhat elitist image, with a pre-selection of high performers who need to meet increasingly high demands.

After many years of falling enrolment, Sweden has been able to accomplish a turnaround. Lower (up to 16) and higher (3-year gymnasium) secondary education offers 17 National Programmes (including the Natural Science, Electrical Engineering and Technology Programme) which allow the student to go to higher education. Since 1995 more time has been allotted for SciTech subjects, including technology as a separate subject, in lower and upper secondary school (Ministry of Education, 2003c). The initiative to improve science teaching through active collaboration between science centres and teacher training has led to an increase of 15% in enrolment in secondary science programmes (20% increase for females). The supplementary

secondary school year (SciTech Basis Year in the upper cycle) seems to have been instrumental in this turnaround.

S&T is light but mandatory (Germany and the UK): In Germany, certain elements of science education are taught, usually compulsorily, until as late as two years before high school completion. Therefore, maths and science cannot be avoided. However, some decision-making early on will still guide the student in the direction of science or the arts.

Yet, more specialized science courses are offered in the last two years of secondary school. This is when most opt-outs occur, but it is possible to decrease the number of S&T-oriented studies even earlier. S&T-related subjects are very unpopular.

In the UK, pupils are required in nearly all cases to attend school until the age of 16, at which time they take a number of GCSEs (exams), commonly in around eight subjects. Education is not compulsory after the age of 16, but around 60 per cent of pupils will study full time for AS-levels, A-levels and/or more vocational qualifications. This generally occurs in Year 12 and Year 13 or a further education college. Since the introduction of the National Curriculum in England in 1989, all students study a balanced science curriculum containing math, biology, physics and chemistry between the ages of 5 and 16. Double sciences at GCSE are a solid grounding from which students can go on to study any science subject at A-level. In science, the National Curriculum requires pupils to study a balance of biology, physics, chemistry and aspects of earth science and astronomy; they cannot choose to specialise in a particular area of science until post-16. The system in the Netherlands has similarities with the British system, in that it offers a balanced (national) science curriculum up to the age of 15/16. After age 16, basic mathematics remains compulsory, while a limited number of subjects are chosen following one of four profiles (i.e. nature/science, health/science, culture/society or economics/society).

S&T is not emphasized (Italy): Italy does not provide specific choices in its secondary schooling system. Pupils can choose for *liceo scientifico* and the *liceo classico* at the time they enter secondary school (approximately age 13). The main difference is that the classic liceo provide more Latin and Ancient Greek, while in the scientific *liceo calculus*, maths and physics have a more dominant role. Within these alternatives, there are no diversified curricula or programmes. This choice at the age of 13 does not seem to limit the range of possible further education; obviously, it is an important indicator of what students are interested in. Surveys at higher levels seem to imply that choosing the *liceo scientifico* often leads to S&T-related studies and careers in later life.

The quality of S&T

In principle, the quality of S&T offered in secondary education could be a factor of impact on the supply to higher education. However, it is difficult to determine the quality of education in most environments. In addition, the normative and empirical relationship between choice and quality does not seem to be straightforward. In determining the quality of education in science at secondary levels, we have relied heavily on the outcome of the measurements of international efforts in this field, most specifically the PISA and TIMSS studies.

There seems to be a relationship between the image of S&T, the quality of science teaching and the performance level on international comparisons, with Finland, UK and Sweden at the high end and Italy and Germany at the low. However, there is also one less straightforward result – Ireland (see Table 3-3).

High quality and high priority (Finland and Sweden): The extensive interest in – and relatively high regard for – S&T in Finland is reflected in the achievements of the Finnish primary age groups in international comparisons. Finland consistently scores in the upper quartile of the OECD countries.

Table 3-3
Overview of scores in PISA and TIMSS

	PISA 2000, scientific literacy	TIMSS 1999, grade 8 science
Finland	538	535
Germany	487	-
Ireland	478	-
Italy	478	493
Sweden	500	-
United Kingdom	532	538
Netherlands	529	545

In Sweden mathematics is seen as a basic requirement, with a passing grade necessary to enter further education. There are many programmes that give access to S&T higher education. In addition, students lacking sufficient S&T skills now have the option of taking a supplementary year of mathematics and science (SciTech Basis Year).

Low priority, high quality (the Netherlands, and the UK): Although the image of science in the secondary level is weak, with biology being the exception, the A-levels in the UK are very demanding. This tends to make S&T somewhat less attractive, but it results in high rankings in international comparisons (PISA, 4th and TIMSS, 9th).

Low priority, lower quality (Ireland, Italy and Germany): In Germany S&T subjects are unpopular partly as a result of traditional ways of teaching and the low practical nature of the subjects; Germany performs in the middle range in mathematics and slightly better in natural sciences.¹² Ireland and Italy don't score too well in international comparisons. Italy is within the lowest third of OECD countries on all three focuses (literature, mathematics and science), and geometric skills are particularly weak. The level of teaching was perceived to be low and mainly aimed solely at the acquisition of knowledge. School reform through the SeT project, begun in March 2003, should improve teaching skills and interest in S&T. For many years science was taught on a rather traditional, cerebral and non-practical footing in Ireland, or 'despite major reforms ten years ago. The new national curriculum should change this and schools with a more practice-oriented science curriculum are already experiencing an increased uptake.

The S&T curriculum

In Finland secondary schools have initiated intensive cooperation with universities and polytechnics with regard to S&T subjects, to improve the success of pupils continuing their studies. In Ireland the whole curriculum (from primary through to upper secondary) will become more practice oriented. To change the image of science, the marking system for the upper secondary science courses has been reformed, courses are becoming more flexible, and students are offered more support. The new structure for AS and A-levels in the UK is aimed at broadening the range of subjects that students can choose in the upper cycle.¹³ In time, this should hopefully also lead to more science A-levels. In addition, the UK is implementing the Specialist School Programme that is based on secondary schools emphasizing a selection of subjects within the curriculum and increasing the level of education as well as attainment in these subjects. Schools work closely with similar schools in the area and with industry to improve the match between education and necessary skills. A school may choose a single or a double specialty

¹² <http://www.mpib-berlin.mpg.de/TIMSSII-Germany>

¹³ An AS-level is about half an A-level. So introducing AS-levels makes it possible to partition (science) courses and lower the threshold.

out of ten options, four of which are S&T oriented (engineering, mathematics & computing, science, and sports & technology). This early specialisation has also led to higher grades and higher GCSE-grades in the specialisation subjects.

Female participation in S&T

In all countries reviewed, secondary education is compulsory, so the gender distribution will reflect the distribution in the population. When focusing on subjects however, distinct patterns of gender dominance appear. In particular the male dominance in technology-related subjects is an established fact in many countries, even in Finland, which has tried for decades to influence the gender balance. From a policy point of view, tapping into the female inflow to higher education and rerouting a subset of women towards S&T is an attractive alternative way to increase the supply of (potential) S&T students. To achieve this one would need to ensure that a sufficient number of girls do not drop S&T-related subjects in secondary school.

There is only anecdotal evidence regarding subject choice at secondary school level (details are provided in Appendix A). This evidence supports the stereotypical categorisation in hard science or 'boys' subjects' (physics, engineering and construction) characterized by male dominance (less than 10% females) and the soft sciences or 'girls' subjects' (biology, chemistry and non-S&T) where the female participation is above 50%. Subjects such as mathematics, ICT and design are indeed male dominated, but seem less gender stereotyped thanks to a significant proportion of females participating (25-35%).

While there is a range of policy measures and initiatives specifically addressing the issue of increasing female participation in S&T (described in chapter 6), there are complex psychological dynamics that underlie this gender-related choice behaviour. What this means for the effectiveness of this type of policy is discussed in chapter 7. At this time we can establish that specific curriculum reforms, and the facilitation of a 'course correction' at the end of secondary education, seem to have a positive effect on S&T choice for girls and young women.

Table 3-4
An assessment of performance regarding supply

	Demographic developments	Explicit S&T in PE	Place S&T in SE	Priority/ Quality outcome	S&T curriculum orientation
Finland	++	+	++	+ / +	industry
Germany	-	+	-	- / -	
Ireland	++	-	++	- / -	practice
Italy	-	-	Separate schools	- / -	
Sweden	+	++	++	+ / +	
UK	+	++	+	- / +	specialisation
Netherlands	++	+	profiles	- / +	

Conclusions

In Table 3-4 we have summarized the main results regarding supply into higher education. Again Finland emerges as a 'front runner' closely followed by Sweden, Ireland and the UK. In this group only Ireland's low score on priority and quality is somewhat unusual. Based on this

comparison, S&T in the Netherlands should be in a better shape, as it has many of the same advantages as the four countries mentioned above. Perhaps the early specialisation through the profiles in secondary education hampers a free flow of school leavers into S&T-related studies. Germany and Italy are clearly lagging behind and should begin to take action to prevent dropping back further.

Influencing study choice

This chapter presents an overview of the inflow of students into higher education, expressed in entrants, stock of student population, and the share of female participation. The overview combines a benchmark situation around 2001 with a long-term perspective illustrating the developments with regard to the outflow from higher education in the last 25 years, and establishes how the countries arrived at their current position. Subsequently, the overview will focus on factors that influence the choice behaviour of students, and compare these across the countries surveyed. Among these factors are entry requirements, financial provisions, the image of S&T, and the quality of education and learning environment.

A benchmark comparison: higher education and S&T uptake around 2001

The first step in the analysis of developments in the higher education S&T was to construct a detailed comparison for a benchmark year as close as possible to the present (in this case the year 2001).

The main questions concern the statistical explanation of revealed patterns of student choice:

- Can international variations in the share of S&T in higher education be attributed to differences in the choice for or against S&T, or are they inherent in the importance of higher education itself? In the first case, the number of higher education students (per 1,000 population from the ages of 20 to 29) would be more or less the same in each country, but the share of S&T would be different. In the second case, the shares of S&T could be the same but there would be differences in the relative number of higher education students.
- If students choose against S&T, which fields of study do they select? And are those fields underrepresented in countries where S&T is a major study field?

The analysis will look at two main groups of higher education students: new entrants and the total student population.¹⁴ Table 4-1 shows the relative sizes of S&T subjects compared to each of these two groups and also includes the share of graduates.

¹⁴ The data cannot be made absolutely comparable. Even when the ISCED is applied and when national data is rearranged according to a consistent classification, there remain differences. For example, in some countries educational sciences and teacher training are included in higher education, whereas in other countries they are classified separately. Some of the observed patterns may therefore be statistical artefacts.

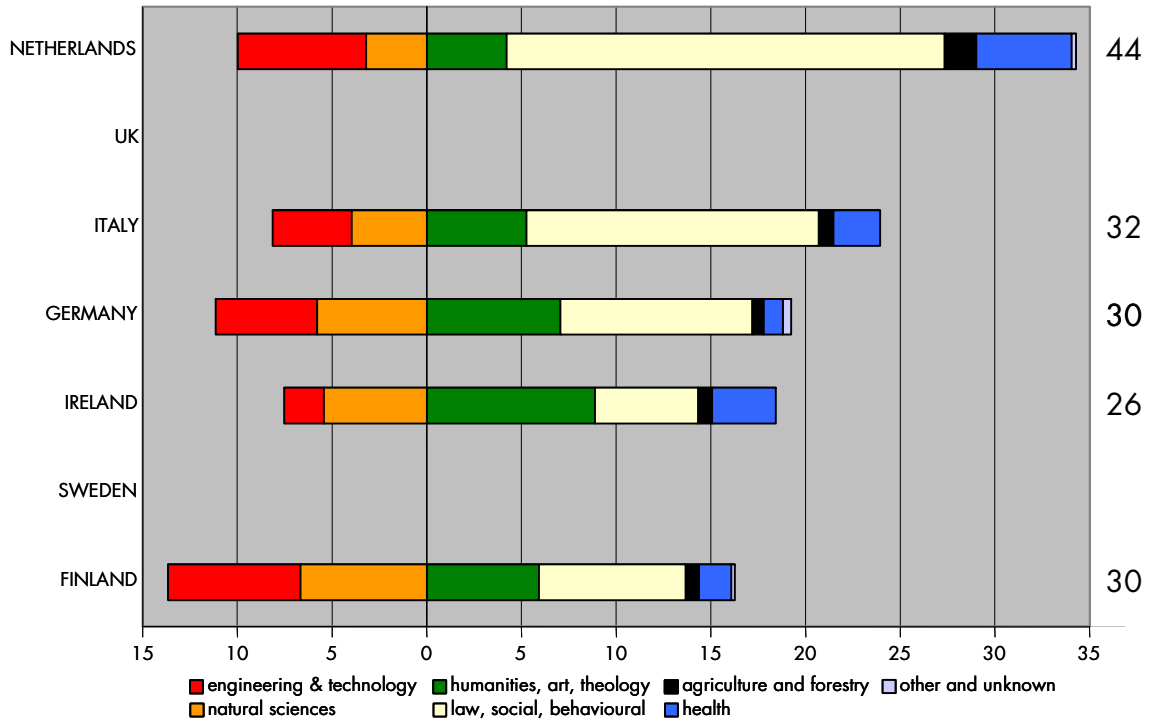
Table 4-1

Total numbers of new entrants, enrolled students, and graduates in higher education in the six comparison countries and the Netherlands, c. 2001/02

	FIN 2002	ITA 2000/01	SWE 1999/2000	UK 2001/02	IRE 2001/02	GER 2001/02	<i>NETH</i> <i>2001/02</i>
Population aged 20-29	631,697	8,277,503	1,100,404	7,730,077	619,024	9,572,390	<i>2,102,251</i>
New entrants							
Agriculture and forestry	2%	2%	n.a.	n.a.	3%	2%	<i>3%</i>
Health	5%	7%	n.a.	n.a.	12%	3%	<i>9%</i>
Humanities, art, theology	18%	15%	n.a.	n.a.	32%	23%	<i>7%</i>
Law, social, behavioural sciences	23%	44%	n.a.	n.a.	20%	33%	<i>41%</i>
Educational sciences	10%	8%	n.a.	n.a.	7%	0%	<i>22%</i>
Natural sciences	20%	11%	n.a.	n.a.	19%	19%	<i>6%</i>
Engineering & technology	21%	12%	n.a.	n.a.	8%	18%	<i>12%</i>
Other and unknown	1%	0%	n.a.	n.a.	0%	1%	<i>0%</i>
Student population							
Agriculture and forestry	2%	2%	0%	0%	3%	2%	<i>3%</i>
Health	7%	6%	12%	14%	10%	5%	<i>10%</i>
Humanities, art, theology	20%	15%	18%	15%	29%	27%	<i>8%</i>
Law, social, behavioural sciences	24%	44%	32%	23%	11%	32%	<i>40%</i>
Educational sciences	8%	6%	9%	4%	12%	0%	<i>21%</i>
Natural sciences	16%	10%	9%	15%	21%	17%	<i>6%</i>
Engineering & technology	21%	16%	18%	10%	13%	16%	<i>13%</i>
Other and unknown	0%	0%	1%	20%	0%	2%	<i>0%</i>
Graduates							
Agriculture and forestry	2%	2%	1%	0%	1%	3%	<i>3%</i>
Health	11%	9%	20%	10%	8%	10%	<i>11%</i>
Humanities, art, theology	19%	13%	8%	20%	6%	22%	<i>7%</i>
Law, social, behavioural sciences	24%	44%	27%	24%	35%	33%	<i>35%</i>
Educational sciences	13%	4%	18%	4%	2%	0%	<i>25%</i>
Natural sciences	15%	10%	5%	18%	17%	14%	<i>5%</i>
Engineering & technology	15%	17%	21%	10%	18%	18%	<i>13%</i>
Other and unknown	1%	0%	0%	13%	14%	1%	<i>0%</i>

Figure 4-1

The number of new entrants per 1,000 population in the 20 to 29 age group per field of study and in total in six countries, c. 2001/2



RAND MG270 4.1

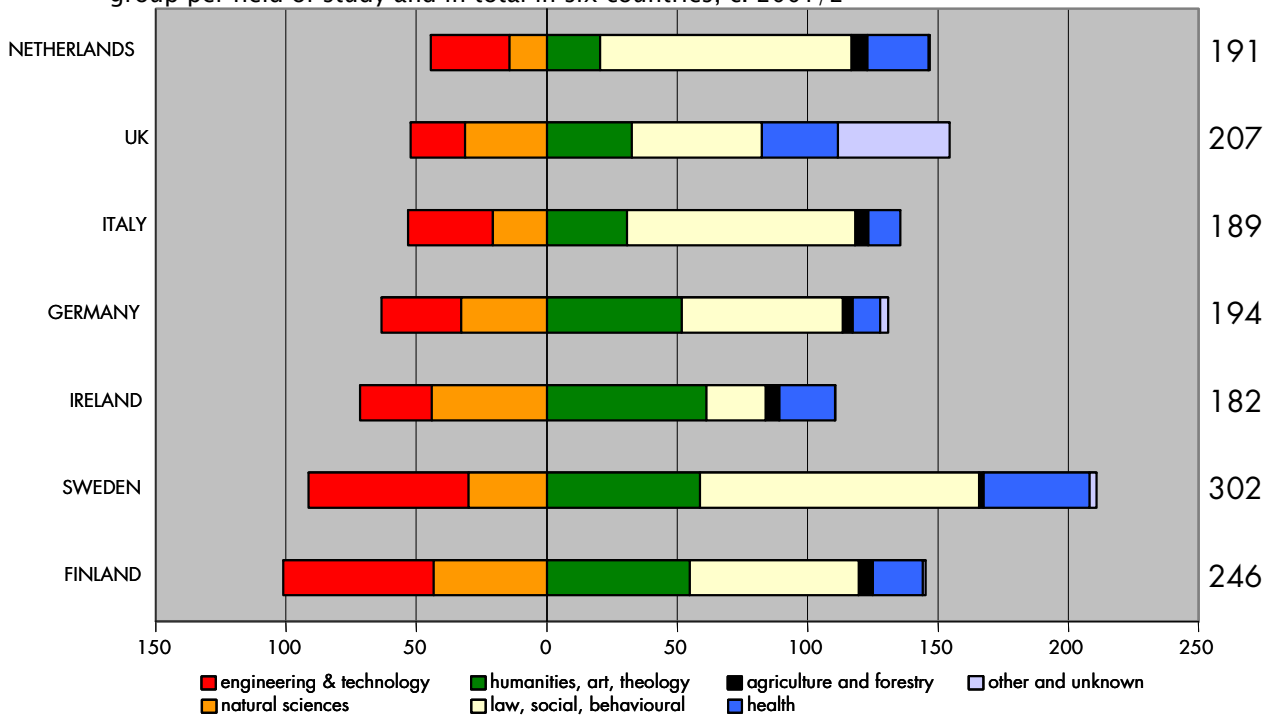
New entrants

The differences in the number of new entrants into S&T across countries are mainly the result of a choice between S&T and other subjects rather than a reflection of differences in the total number of students in higher education as such (see Figure 4-1).¹⁵ In the Netherlands and Italy, new students clearly favour law, economics, and social sciences; health is also popular in the Netherlands. The relative size of the group of new entrants in Germany, Italy and Finland is comparable, but a far greater proportion of Finnish first-year students prefers S&T over non-S&T subjects.

¹⁵ In Figure 4-1, the length of the bar indicates the absolute number of new entrants per 1,000 in the relevant age group. S&T disciplines are placed at the left of the 0, facilitating comparison of the absolute number of S&T entrants.

Figure 4-2

The number of students in higher education (stock) per 1,000 population in the 20 to 29 age group per field of study and in total in six countries, c. 2001/2



The student population

Five out of the seven countries (as shown in Figure 4-2) have a similar stock of higher education students in S&T. Only in Sweden and Finland is the number of students markedly larger.¹⁶ In Germany, the Netherlands, Ireland, the United Kingdom, and Italy differences in the number of S&T students reflect the choice of students between S&T and non-S&T subjects rather than a choice for or against higher education.

The Netherlands has the lowest ratio of S&T students to population in the 20 to 29-year-old age group. Italy, the UK and, to a lesser extent, Germany have marginally higher ratios. Finland and Sweden, and less obviously Ireland, clearly outperform the other countries in our sample. Finland performs well in both natural sciences and engineering and technology studies. The Netherlands scores particularly badly in the natural sciences: most other countries have twice or even three times the Dutch proportion. Ireland and Finland are the best performers in the natural sciences. The Dutch position in engineering and technology may not be superb, but is certainly not that much of an outlier. Germany and Italy are on the same level, while the UK and Ireland are worse. Sweden and, as indicated, Finland, have much greater shares (approximately twice as many) of engineering and technology students per 1,000 population in the 20–29 age group.

A long-term perspective on S&T uptake

A snapshot of the current student population presents the urgency of specific issues relating to S&T. It obviously does not show whether the current status is the result of positive or negative developments (either influenced by policy or not) in the past. In this section, we have used time

¹⁶ In Figure 4-2 the length of the bar indicates the absolute number of students (x1000), S&T disciplines are placed at the left of the 0, facilitating comparison of the absolute number of S&T students.

series of the student population (entrants, enrolment, and graduates) to examine differences in the levels and trends in S&T in the six comparison countries.

National similarities notwithstanding, the experience of the six countries and the Netherlands is vastly different. Table 4-2 compares the rates of growth of the student population in each of the seven countries by field of study and gender in the approximate period between 1990 and 2000. The main observations are:

- The number of men in technology/engineering has been on the decline for over ten years.
- In Italy and the Netherlands the male student population in higher education has declined across the board. The female student population performs marginally better, especially in technology (Netherlands) and non-S&T subjects (Italy).
- The student population in S&T in Sweden and Finland (for both science and technology studies), the UK¹⁷ and Ireland (especially in science studies), is characterized by rapid growth, both for men and women.

Growth rates refer to the development of the size of each individual subsection of the student population and then only between two benchmark years. In addition, an analysis of growth rates ignores the relative size of subgroups (e.g. gender or fields of study).

We also want to gain a better understanding of the share of S&T students relative to students in other fields, and of the share of female participation relative to men. This understanding is created by examining the relative (percentage) shares of S&T in the total number of new entrants, enrolled students and graduates and the relative share of women in S&T and other fields of study.

¹⁷ In the UK, this growth is primarily due to increases in the numbers studying IT and the biological sciences, with the overall increase masking downward trends in the numbers studying mathematics, engineering, chemistry, and the physical sciences. For example, the number of entrants to chemistry degrees dropped by 16% between 1995 and 2000. (Roberts, 2002)

Table 4-2

Compound average growth rate of the student population in science, technology and all other fields of study in the 1990s (%)

		Men			Women		
		science	technology	all other	science	technology	all other
Finland	1990–2000		4.4	1.8		5.3	3.3
Germany	1990–2000	0.5	-2.3	0.9	2.1	3.7	3.3
Ireland*	1990–1997	2.8	-2.4	6.6			
Italy	1995–2000	-1.7	-2.4	-1.4	-0.3	0.4	1.8
Sweden	1990–2000		5.3	2.7		9.1	1.7
UK	1990–1999	6.1	-1.0	6.8	8.0	2.5	9.0
<i>Netherlands</i>	<i>1992–2000</i>	<i>-1.9</i>	<i>-1.9</i>	<i>-2.3</i>	<i>-0.4</i>	<i>1.8</i>	<i>-0.5</i>

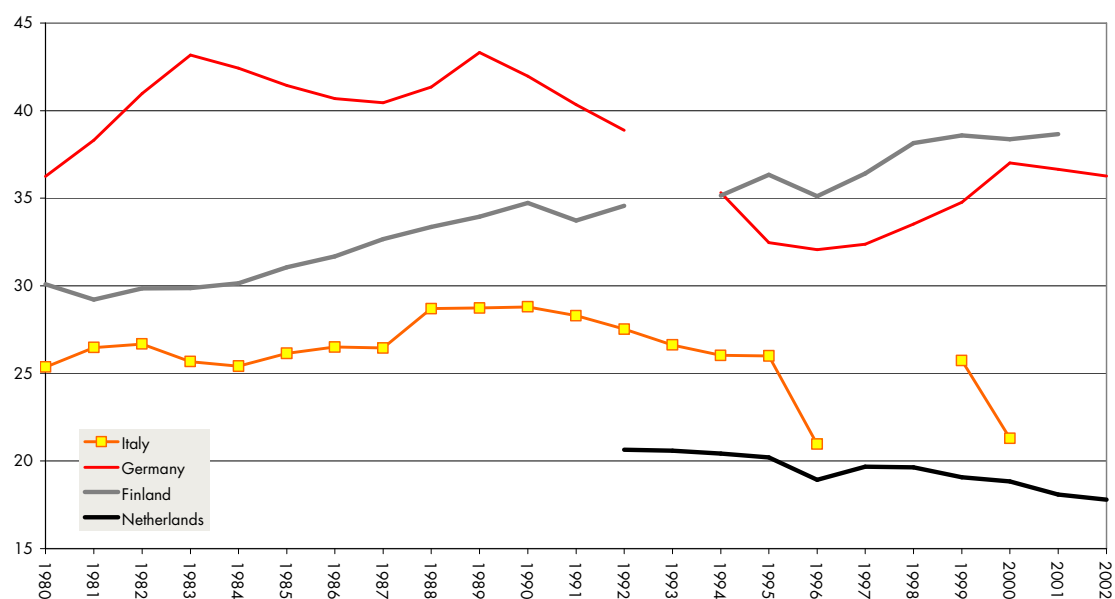
* The numbers for Ireland do not differentiate between men and women

New entrants

The choice for S&T by first-year students has fallen since the late 1980s in Germany and Italy and since the late 1990s in the Netherlands. Only in Finland has there been a steady increase in the share of S&T. In the Netherlands, however, the share of S&T students in the total number of new entrants is remarkably low.

Figure 4-3

The share of new entrants studying science and technology in higher education, 1980–2002 (%)

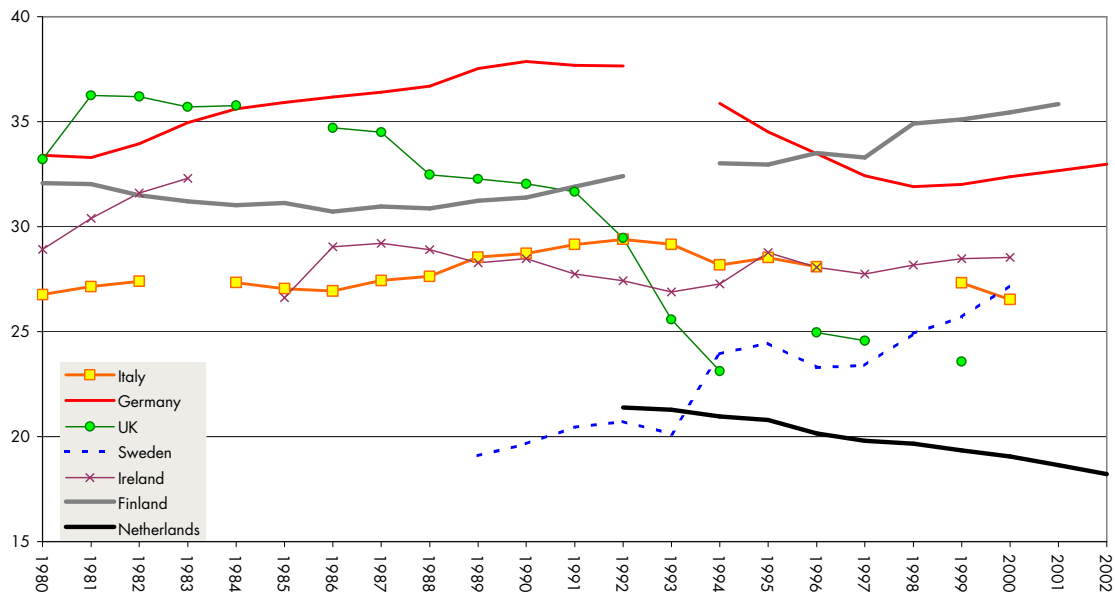


Stock

The share of natural sciences, engineering and other S&T fields of study in the student population was generally higher in the 1980s than it is today. Only in two countries has the share of S&T increased: Sweden and Finland. In the UK, its share has dropped from over 35% in the early 1980s to about 32% in 1990 and less than 25% in the late 1990s. In Italy the share of S&T has been on the decline since the early 1990s. Once again, the Netherlands has the lowest percentage share of S&T.

The Netherlands clearly shows up as a country where relatively few study S&T. It deserves to be labelled as a country ‘falling further behind’. Sweden, now classified as ‘forging further ahead’, actually started slightly below the Netherlands, but seems to have increased its S&T proportion by almost 5% since 1990. Based on this data the country should be labelled ‘catching up’. In Italy and Ireland, S&T has remained more or less stable (26–30%). Finland displays a slow but steady rise and S&T comprises about 36% of the student population in higher education. There is greater concern over Germany, but its position is not as bad as it is perceived. Until the early 1990s, more than 35% of all students were enrolled in S&T. At present, even with a drop in the late 1990s – followed by some recovery – it is only slightly below Finland and well above the others. The UK is a different matter altogether, with a steadily decreasing proportion of S&T, losing approximately ten percentage points over 15 years.

Figure 4-4
The share of students enrolled in higher education studying science and technology, 1980-2002 (%)



Female participation in S&T in higher education

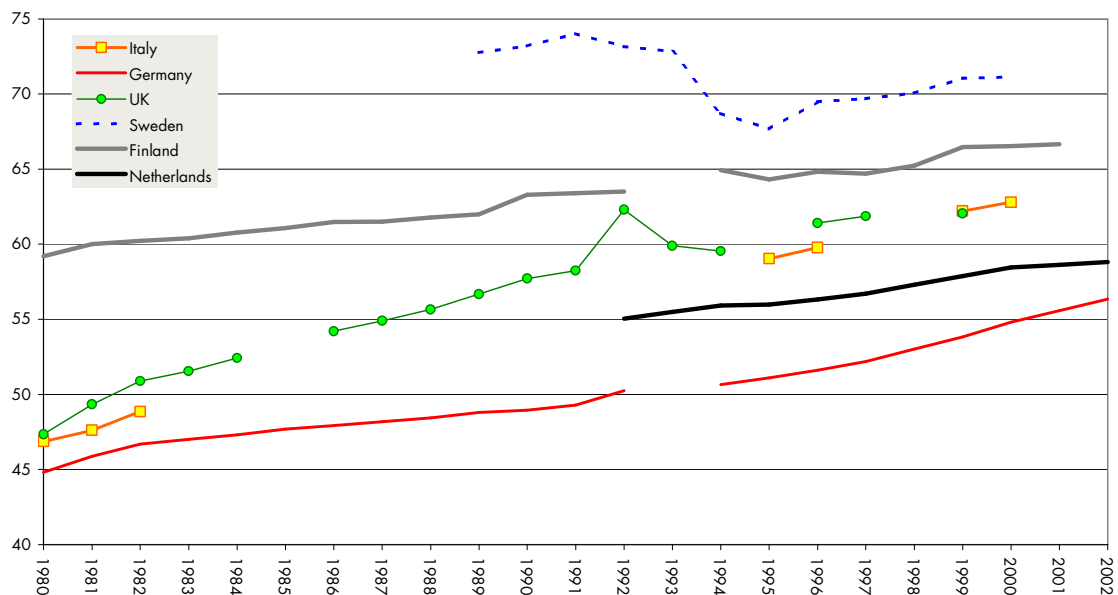
Women are gaining on men in higher education. In Germany, female participation is approaching 40% and in the UK and Ireland women now outnumber men. The shift is almost always more pronounced in the non-S&T disciplines, such as social sciences, law, and health. Yet even in S&T women are gaining ground.

Even in Finland, where most initiatives aimed at increasing female participation in S&T are relatively successful, the increase is larger in non-S&T areas. In Ireland, female students now outnumber men at the Institutes of Technology, which now account for about 40% of higher education.¹⁸ In the UK, the gender shift is more pronounced in S&T, particularly in chemistry but also in engineering (where the share of women doubled), computer science and bioscience (Greenfield, 2002). In Sweden, women are well represented throughout higher education. There is only one discipline – engineering – where the dominant gender (male) comprises more than 60%. In Italy, where the gender shift is not a priority, women have made some gains in engineering but this is almost masked by the general increase in enrolment. Germany is characterized by a marked S&T decline (especially in engineering) while the general trend is a rise in female participation of about 2–4% each year (in social sciences languages, economics, law, arts and medicine). Figure 4-5 and Figure 4-6 compare the development of the share of women in S&T and non-S&T subjects since 1980. Virtually every series shows an increase in female participation. The two figures lead to three observations:

- The share of women is considerably lower in S&T than in the other fields of study. This can be attributed mainly to engineering and technology, where women usually account for only a few percentage points.
- Finland (in S&T) and Sweden (in non-S&T) are two exceptions in that the share of women remained more or less constant. On the other hand, women already had a substantial share in the number of students at the start of the period. The emancipated stance of the Scandinavian countries is evident in the development of the share in non-

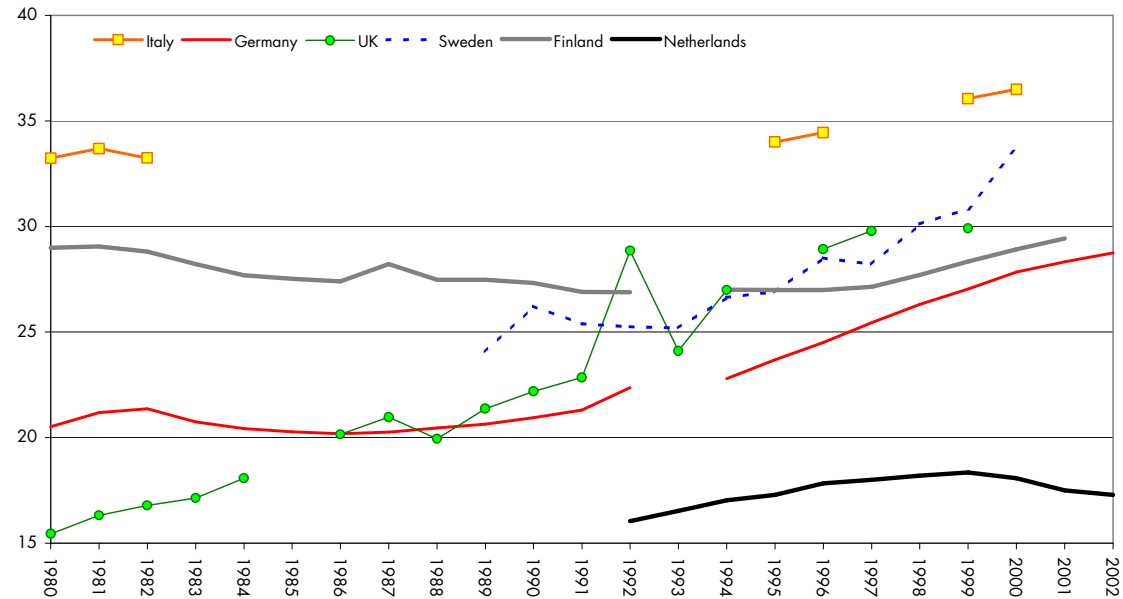
Figure 4-5

The share of women in the student population in all other fields of study, 1980–2002 (%)



¹⁸ RAND MG270 4.5 <http://www.oecd.org/dataoecd/41/40/2675784.pdf>

Figure 4-6
The share of women in the student population in science and technology, 1980-2002 (%)



RAND MG270 4.6

S&T students. In S&T itself this stance is less obvious.

- The Netherlands and, to a lesser extent, Germany are among the worst performers in terms of gender. In the 1990s, Dutch women contributed at least 10% less to the total student population in S&T than in the other countries. In all other subjects only Germany performed worse than the Netherlands, which is still 5–10% below the other countries.

Aspects of higher education influencing study choice

Issues influencing study choice can be of a formal or informal nature. In this section we focus on the formal issues such as

- entry requirements, entry limits, entrance exams, etc.;
- financial arrangements (imposed or not by governmental policies) might impact the (relative) attraction of studies;
- image of S&T;
- quality and learning environment.

More informal influences such as perceptions of good teaching etc. are in part discussed in chapter 7.

Entry requirements

The usual access to higher education runs through preparatory secondary education (e.g. upper secondary schools, A-levels at secondary school etc.), but due to pressures on S&T demand, as well as policy goals to increase the level of education overall, some countries have designed alternative routes. The requirements for access in the six countries vary only to a limited extent. Access is either regulated by numerous clauses (primarily through grade averages or performance in secondary education) or by specific entry exams. These procedures, however, are generally not

Table 4-3
Overview of moments and direction of choice for S&T in secondary education for the various countries surveyed

	Entry into HE dependent on choice	Alternative routes
Finland	No, entry exam is ultimate selection criterion	Yes, rarely used however
Germany	Average grade in selected subjects drives admission	Through vocational education
Ireland	Average grade in Leaving Certificate subjects drives admission	Not really
Italy	No, entry exam is ultimate selection criterion	Not really
Sweden	Various S&T-related grade testing determines continuation	Various alternatives
United Kingdom	Average grade in A-levels important, sometimes entry exams	Widening of access possibilities but focus is still on A-levels.
Netherlands	<i>SE diploma and profile (chosen subjects)</i>	<i>Through vocational education</i>

different across disciplines or programmes. Entry exams are heavily influenced by admission limits (where they apply); in that sense, given the generally lower levels of entry for S&T studies, the entry exams for these studies tend not to be as competitive.

Access through secondary school: In Germany, the UK, Ireland and the Netherlands, access to higher education is based on performance in secondary education. Germany and Ireland have more or less centralized application mechanisms that control the allocation of students to individual institutions and priorities on the basis of the pupils' results in secondary education¹⁹. In the Netherlands, entry also depends on choice of profile. The nature/science and health/science profiles provide access to S&T disciplines and some 45% of pupils in secondary education choose these profiles. In the UK, entrance exams are not commonly used except for Oxford and Cambridge, but the required A-levels need to be achieved in the appropriate programme. To enter higher education in the UK, a minimum of two A-level subjects is required. While the number of A-levels being taken overall has increased, the number of A-levels taken in mathematics and physics are decreasing yearly. As mentioned before, girls are choosing biology and chemistry more often (Greenfield, 2002).

In Italy, the only access route is through the state high school diploma (*Diploma di Esame di Stato*) and the type of secondary school often indicates the type of higher education that will follow. In addition to the high school diploma, additional testing takes place at higher education institutions. Some 70% of all pupils enrol in higher education, and as such the inflow in S&T, in particular the applied areas of S&T, does not seem to be low in Italy.

In Sweden, some 40% of secondary pupils enter HE immediately after secondary school, and another 30% follow within five years. The entry requirements are the same for all programmes and courses: a diploma of upper secondary education and a certain minimum of credits required for specific entry. In Finland, students enter the universities through entrance exams that are, in S&T, mostly based on upper secondary school courses. Also the success in the matriculation exam and upper secondary school grades are taken into account. In many studies, parts of the

¹⁹ For example, this is based on the results of a maximum of six subjects taken as part of the Leaving Certificate.

students are selected based on these results only. There is natural competition across universities so that it is hardest to get in to the universities or on to the programmes that are perceived to be of highest quality (e.g., Helsinki University of Technology among technical universities, Helsinki University among other universities).

Alternative routes to HE: In Finland, it is always possible to enter university or polytechnic through the entrance exam or based on the matriculation examination and upper secondary school grades. There are also alternative routes, but these are used relatively rarely. It is more common to switch between programmes once entered in higher education. In general, it is also possible to enter a university by passing certain basic courses in the Open University.

In Ireland, only Leaving Certificates give access to HE, but because of high demand and competition between universities, these certificates do not always give direct access. Students are ranked by their results on the six subjects most relevant to the study of choice. Pupils wishing to continue in S&T, but with only applied certificates, need to fulfil extra training first.

Financial issues

Financial issues influencing enrolment in general, and perhaps S&T in particular, involve matters such as tuition fees, grant and loan systems, general support and funding. Although tuition fees do not generally seem to influence enrolment, particularly when student support is sufficient, it could be that when there is some differentiation across disciplines, they could influence inflow and outflow (Frinking et al, 2003). There is no evidence of fee differentiation between S&T and non-S&T. This could result in a disadvantage for S&T students as they tend to take longer to graduate. Depending on the student financing system, and in particular the loan system, this could lead to higher study debts for S&T students and perhaps be a disincentive to choose S&T.

Tuition fees: Sweden, Finland, Ireland and Germany do not charge tuition fees for full-time state tertiary education. The latter three countries only charge a small contribution (approximately €60 a year) towards the use of institute facilities and health care.

In Ireland, private colleges do have the option to charge fees. In Italy, tuition fees differ by institute and cover about 20% of the real cost. Currently in the UK, where a substantial proportion of higher education is provided by private institutions, the undergraduate fee is more or less fixed, and differentiation is sought through differing access requirements, with 'high quality' universities setting higher standards.²⁰ There is no differentiation with regard to discipline; in the UK fees are differentiated by type of course (part-time or post-graduate) and by nationality of the student (UK students pay least, non EU-students pay most). The new, recently approved fee system will mean major changes, but these are not aimed at any specific discipline.

The Netherlands has a fixed fee for full-time EU-students (up to 30 years old) of approximately €1450. Fees for part-time or non-EU students or students over the age of 30 vary per institute.

Student financing: Finland provides substantial student financing, with specific grants for living expenses, while rent and meals at the university are subsidized. Students can take out loans for additional funds or find work. All this can add up to between €644 and €944 per month, with a maximum €200 per month loan. Technology students can request five months additional support. Sweden supports students aged from 16 to 55. The ages 16 to 19/20 are supported through the 'studiehjälp' (of about €92 per month) aimed at helping them through secondary school. From 20 upwards there is the 'studentmedel', part grant, part loan. As in Finland, the grant is subject to placing a cap on a student's income from work. The loan is independent of any other income, is reduced after the age of 41 and needs to be paid within 25 years of graduation. There are several types of additional grants and loans as well (NAHE, 2003; Salerno, 2003;

²⁰ In the new system they will be allowed to charge a substantially higher fee.

Ministry of Education, 2003b). In addition to the high level of public funding, Irish students can also request a grant to cover tuition costs and maintenance, while students at private colleges can apply – on a limited basis – for tax exemptions or relief provisions.

The Netherlands issues a basic grant to all full-time students starting HE before 30. Additional grants are available depending on the income of the parents. The grant system is supplemented by a loan system for the nominal study duration plus 36 months.

In the UK, all students will need to pay back tuition fees after graduation, with discounts for ‘poorer’ students and a limit placed on the proportion of earnings used to service the loan. Government only provides grants and hardship funds under extreme conditions. Research council studentships have replaced the abolished grant system to a certain degree, but there is discussion about reintroducing it to promote and protect access for less advantaged students.

German students rely on their parents for financial support. Additional support is available but differs between regions (‘Länder’). Foundations and companies sometimes sponsor undergraduate stipends.

Italy does have a grant and loan system, dependent on family income. Only 10% of the students receive this kind of grant and it is unclear to what extent this is effective in increasing enrolment from disadvantaged backgrounds. There are other, larger grants and a loan system (not very common) as well as subsidized student accommodation and meals.

Image of S&T

The image of S&T within a country is often a reflection of different contributing factors. Many of these factors are discussed in this report, such as the curriculum of S&T, the potential for educational and career development, and the overall perception of S&T within society. Measuring an overall image of S&T is rather difficult, although surveys do attempt to capture broad societal perceptions. Unfavourable societal images of S&T are often related to the perceived potential harmful effects of the results of science.

Across the countries surveyed, fairly different perceptions seem to be in evidence. In Finland, the **image of S&T is good**. S&T is well represented in media and emphasis has been put on popularisation of research results. Career opportunities are abundantly obvious with substantial involvement of the engineering and electronics industry in education.

In Ireland and the UK, the image of science is fairly good (DfES, 2003). Enrolment in science-oriented secondary education and applied S&T courses is high, although it is falling in the UK among male students (Roberts’ Review, 2002). On the other hand, students believe a career in S&T is difficult and unprofitable. In these countries the perceptions about career opportunities are not fully supported by statistical evidence (see also the previous chapter).

The **bad image** that science has in Germany persists into higher education. Here as well, science is seen as dull, difficult and future earnings are not expected to be high. All in all, science is often perceived as just not being ‘worth the effort’. Furthermore, career prospects in applied science are rather rigid, something which could be improved. The image of science in Sweden is also not good, which is a constant concern for policymakers and has resulted in a number of initiatives.

In the Netherlands, S&T is seen as ‘too narrow’ (approximately 30%), ‘too difficult’ (22–26%) and/or ‘too theoretical’ (25–30%). However, these are not the most often mentioned reasons not to pursue a career in S&T; students do not expect it to be difficult finding a job following an S&T education, but they do think that there are insufficient *attractive* career prospects (approximately 50%) and that S&T in general is too far removed from society (34–44%).²¹

²¹ Source: Studentenmonitor 2003 in press

Table 4-4
Ratio of students to teaching staff in public and private institutions in tertiary education, calculations based on full-time equivalents (2000)

	Tertiary-type B education	Tertiary-type A and advanced research programmes	All tertiary education
Finland	n.a.	16.1	n.a.
Germany	14.9	11.7	12.1
Ireland	14.8	19.4	17.4
Italy	6.0	24.1	22.8
Sweden	n.a.	n.a.	9.3
United Kingdom	n.a.	n.a.	17.6
<i>Netherlands</i>	<i>n.a.</i>	<i>n.a.</i>	<i>12.6</i>

Source: OECD, Education at a Glance 2003

Teacher student ratios and quality of S&T

The number of students per teacher is a potential quality indicator, assuming that in smaller classes students receive more attention and are consequently given a better education. Table 4-4 below presents overall student/teacher ratios for tertiary education in the six countries surveyed plus the Netherlands. More precise distinctions of these ratios between S&T and non-S&T subjects are, however, not available.

The quality of research in Finland is above average and due to many years of development, and there are no general concerns regarding the quality of teaching at university or at the polytechnics. However, the rapid increase in student intake especially in IT-related subjects has led to a discussion on the high student-to-teacher ratio. Experiences with international exchange programmes have proved that the quality of Italian S&T graduates, in particular engineering, is high.

In the UK, all levels of science teaching suffer from a lack of qualified teachers, which is due in part to the relatively unattractive earnings. Teacher training is therefore a priority and the national network of science learning centres is being developed to support teachers in acquiring the necessary expertise and skills.²² In spite of this, the knowledge base and quality of science teaching are still very strong. The main concern is to uphold this and expand upon it.

In Ireland, the investments in improving curricula and teacher training have not paid off in higher enrolment or lower drop-out rates. In Germany, teaching methods are still traditional and perceived as being of poor quality. Teachers are becoming aware that this needs to change. In Sweden, specific units – National Resource Centres – have been set up in universities to ensure professional knowledge in the sciences.

Interaction and shifts between S&T and other disciplines

The question here is whether it is possible to switch to or between S&T subjects, or combine non-S&T courses within an S&T major. It seems that where switching is made very easy, it may

²² These centres are developed with the Wellcome Trust, and give science teachers the opportunity to strengthen their subject expertise and develop innovative teaching methods. The Further Education Standards Unit has identified science and mathematics as priorities in developing good practice frameworks for teaching and learning. (Clarke, 2003).

lead to more shifts out of S&T. That said, there is generally recognition of the need for more flexibility and to combine courses, in particular combining engineering with economics and or a foreign language seems to be a general development.

No restrictions: Germany, Finland and Sweden have no restrictions whatsoever on taking non-related courses. Germany sees this basic freedom as the core of the ‘academic individuality’ and the backbone of the concept of ‘Bildung’. In Sweden, this basic freedom of choice even stretches to taking extended breaks from education and changing study programmes etc. (NAHE, 2003; Solarne, 2002). In Finland, the basic freedom to choose any course once at university could even explain the, sometimes low, yield of S&T tertiary education. Because the competition is low for these subjects, students who are really interested in some other (perhaps non-S&T) subject enter university as a S&T student and then proceed to choose courses in the subject they do wish to pursue. There is no clear statistical evidence, but it would seem that this freedom does not lead to observable shifts towards S&T. On the contrary, it seems this freedom is used to circumvent competition in other subjects.

In the UK, there is no fixed system of major/minor subjects, and choosing elective courses outside the chosen discipline is almost always possible. There seems to be an upward trend towards more flexibility.

Interactions or shifts limited: In Italy, students are generally allowed to study only one subject at a time. However, on an institutional level, there are more or less limited opportunities to switch between subjects – with recognition of the exams already taken. Within S&T-related disciplines, this is relatively easy because of the high level of similar courses. It is also becoming more common to require at least one foreign language too (usually English). In Ireland, there are now almost no possibilities to switch and there are only very limited options to combine non-S&T subjects within S&T.

Conclusions

The benchmark comparison shows that Finland's frontrunner position with regard to the number of S&T students is the result of a preference for these subjects, and not a consequence of a much larger student population. The difference in the number of S&T students reflects the students' choice between S&T and non-S&T subjects rather than a choice for or against higher education. While the Netherlands has a relatively large inflow into higher education, students clearly prefer law, social and behavioural sciences to S&T subjects, and the analysis supports the Dutch perception of itself as a country seriously lagging behind in S&T inflow and share. Germany, on the other hand, is not doing as badly as it fears.

Regarding the choice for S&T in secondary education and its consequences on the inflow into HE, it is important to examine the level of finality of the choice. When the initial choice can be reversed – either by postponing the final decision through provision of lower level courses over a longer period, or by providing a 'catch up' year – this leeway makes amending an earlier choice possible and can lead to a shift towards S&T in secondary and higher education.

Access is influenced by entry requirements and the option for alternative routes (circumventing science insufficiencies), by financial issues (fees and the grants and loan system), by the image of S&T, and by the quality of the learning environment in higher education. Two indicators for the latter issue are included here: teacher/student ratio (if low, more attention can be paid to any individual student), and the freedom to explore various disciplines.

We have found no examples of fee differentiation between S&T and non-S&T, which in itself could result in a disadvantage for S&T students. S&T studies tend to take longer. In loan systems this could mean that S&T students build up higher study debts. In an earlier comparison of student financing systems (Frinking et al. 2003), the reluctance to acquire debt appeared to be universal, and this could become a possible disincentive to choose S&T.

Ranking the six countries (and the Netherlands) relative to each other shows again that the Scandinavian countries are the better performers. Germany and Italy perform below average, while the Netherlands would be on a more or less middle position with Ireland and the UK.

Table 4-5
An assessment of performance in six areas

	choice SE amendable	Student financing	alternative routes to HE	S&T image	T/S ratio in HE	Interaction/ interdiscipl.
Finland	++	++	++	++	-	++
Sweden	++	++	++	+	++	++
Ireland	++	+	+	++	-	--
UK	+	±	+	+	-	+
Germany	-	±	+	--	+	++
Italy	-	--	-	+	--	-
Netherlands	±	+	++	±	+	+

Note: A plus or minus does not imply an increase or decrease in numbers or a low or high score in absolute terms. Instead, a plus indicates relative good performance within this sample of countries and a minus indicates relative bad performance.

Outflow: yield and labour market position

This chapter presents an overview of the outflow of students from higher education, expressed in drop-out rates, student retention and graduation levels. As in the previous chapter, the overview combines a benchmark situation around 2001 with a long-term perspective illustrating the developments with regard to the outflow from higher education in the last 25 years, and establishes how the countries arrived at their current position.

There are a number of factors influencing the outflow: the labour market position of S&T graduates and perception thereof by potential new entrants, including employability, salary levels, career development and demand for S&T, career choice, and income.

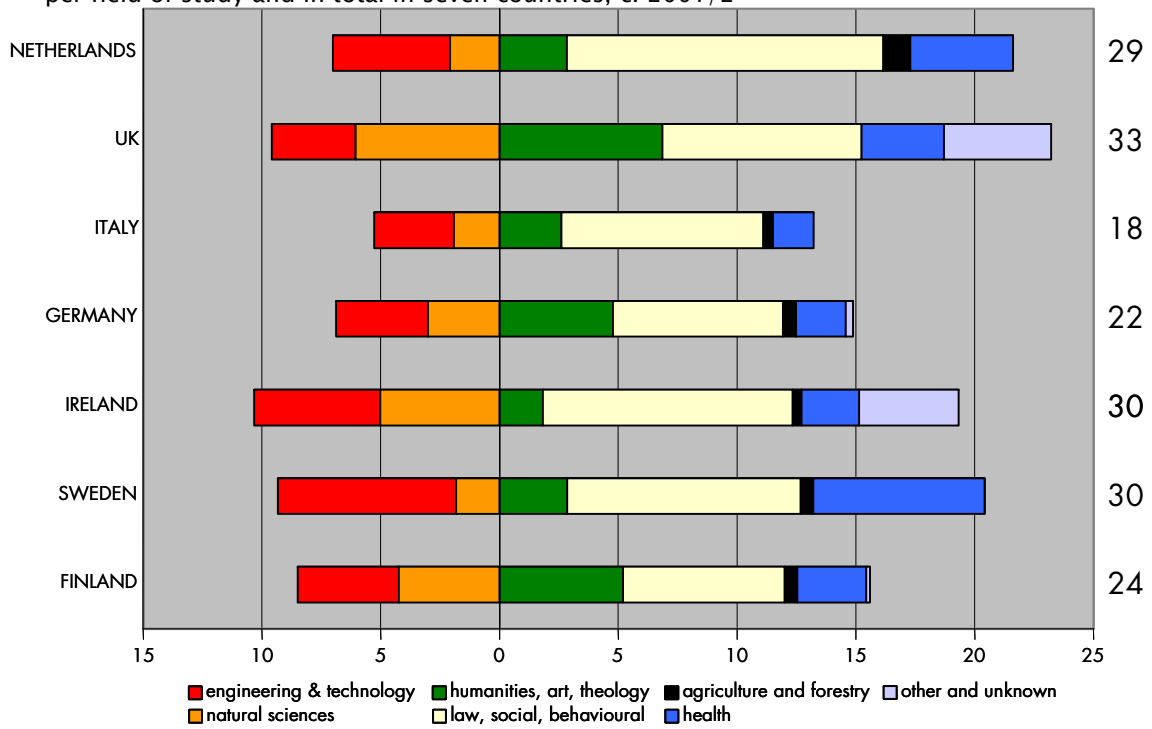
A perspective on S&T graduates

Figure 5-1 gives an indication of numbers of graduates per field of study in the surveyed countries. The relative numbers of graduates in the Netherlands, Ireland, the UK, and Sweden are comparable. There are, however, considerably fewer S&T graduates in the Netherlands. Germany, Italy and Finland seem to have fewer graduates overall, but Finland has about as many S&T graduates as the former four countries. Thus, Finland's lead in S&T seems to have gone at the expense of law, social science and behavioural studies.

The pattern of development of the share of S&T in the total number of higher education graduates is consistent with that of entrants and stock. Germany and the Netherlands have experienced a decline since the early 1990s. Italy and Ireland have long managed to maintain constant levels, although they each had higher S&T shares in the early 1980s. Only in Finland has S&T recently recovered about 30% market share.

Figure 5-1

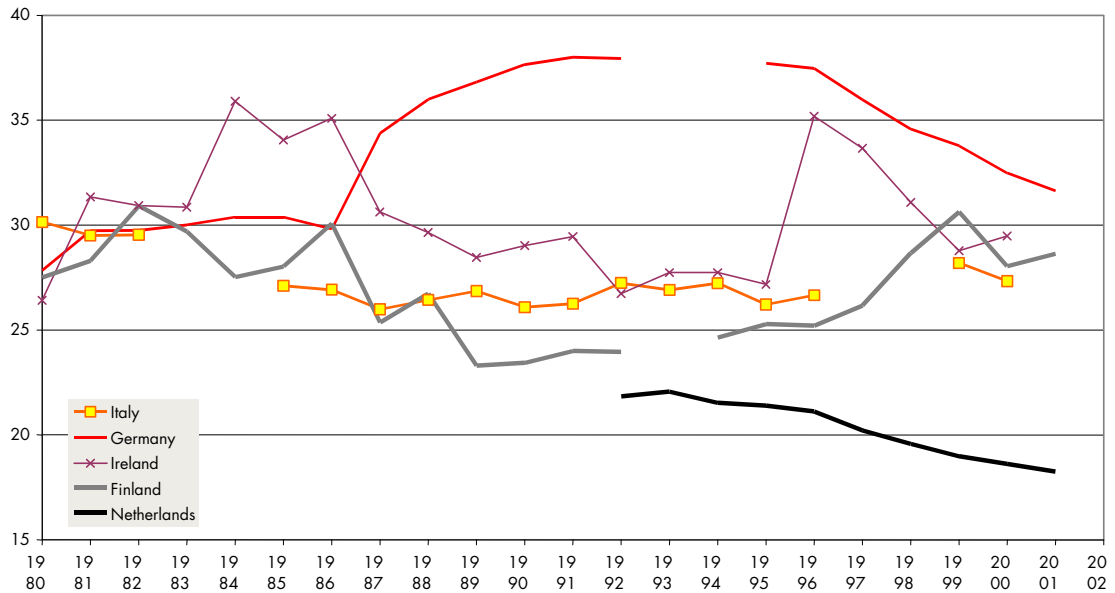
The number of graduates per 1,000 population in the age group of 20- to 29-year-olds per field of study and in total in seven countries, c. 2001/2



RAND MG270 5.1

Figure 5-2

The share of science and technology among graduates in higher education, 1980-2002 (%)



RAND MG270 5.2

Table 5-1
 Estimated drop-out rate of students in science, technology and all other fields of study in Germany, Finland and the Netherlands, average of 2000-2001 (%)

	men			women		
	science	technology	all other	science	technology	all other
Germany	-3	16	-2	10	9	11
Finland		24	1		15	-1
<i>Netherlands</i>	<i>25</i>	<i>28</i>	<i>29</i>	<i>22</i>	<i>16</i>	<i>13</i>

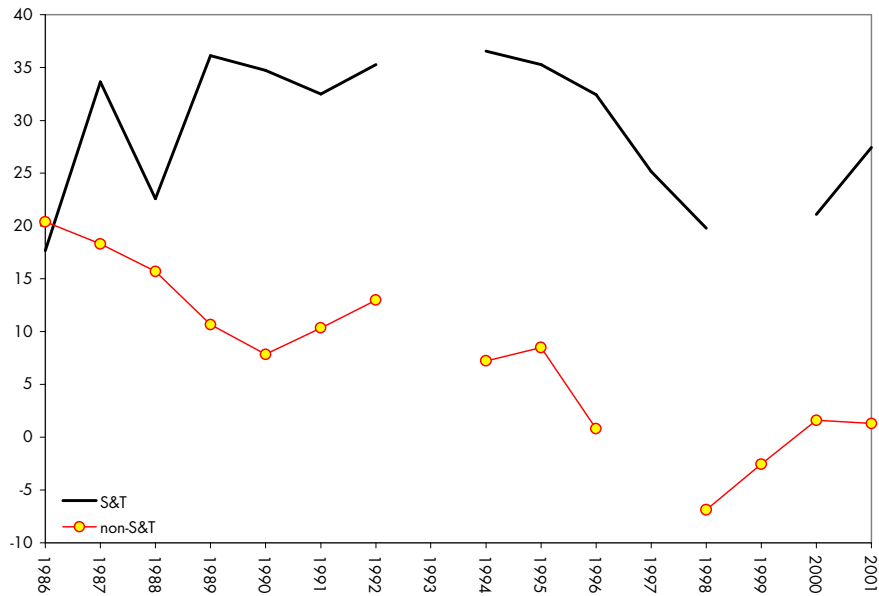
Note: The drop-out rate has been calculated by dividing the difference between the number of graduates in the academic years 2000/01 and 2001/02 and the number of entrants in 1994/5 and 1995/6 by the number of entrants in 1994/5 and 1995/6, assuming an average study duration of six years for S&T and four years for all other subjects. Negative percentages occur when the number of graduates exceeds the number of entrants, which may be explained by switching between studies and changes in the study duration.

In addition to graduation levels, we have also examined the students who have not completed their S&T studies. Explicit data on this drop-out is not easily available. However, the difference between the ratios for entrants and graduates is a proxy for the drop-out rate which is explained by the fact that some switch to an alternative subject outside the S&T domain, while others leave higher education altogether. We have compared the number of graduates in S&T studies in 2000 and 2001 with the number of entrants six years earlier in order to gain a better impression of the drop-out rate.²³

In general, the drop-out rate from S&T is higher than from other fields of study. Only in the Netherlands is the drop-out rate from non-S&T subjects remarkably high, especially for men. This indicates that the relatively small numbers of S&T students have an equally high drop-out rate. This overall picture may indicate that within tertiary education, shifts occur which are not captured by the statistics (e.g., students changing to tertiary or further education outside higher education). Finnish data makes it possible to chart the development of the drop-out rate through time (Figure 5-3).

²³ We also compared the number of entrants four years earlier to assess sensitivity to study duration in this measure. Trends emerging from that comparison were very similar.

Figure 5-3
Estimated drop-out rate of students in S&T and other subjects in Finland, 1986-2001 (graduates as a percentage of new entrants in 1980-1995)



Source: Yliopistot Universitetten [Finnish Universities] 2002; Suomen tilastollinen vuosikirja [Statistical Yearbook of Finland] 1981-2002.

RAND MG270 5.3

This shows that while the ratio of graduates to entrants for non-S&T subjects steadily declined to the point where the assumed drop-out rate was close to zero, the drop-out rate of S&T remains fairly high at between 20 and 25 percent. In the case of S&T in Finland, students very often combine working (part time, but also full time) with continuing their studies, which very often results in prolonged duration and drop-out due to 'lack of time'. This drop-out reflects badly on the yield, while, in fact, the student (and the education) is successful in the sense that the student has entered a profitable career – even before graduation.

Student retention (or yield) in general and for S&T

There are various ways in which the structure of higher education can influence student retention.

One structural aspect is the **freedom to change** subjects or to follow an alternative route. When this freedom is small, students making less than satisfactory progress in an S&T-related subject find it difficult to change or repeat parts of the study, and so must drop out of the subject altogether (Germany and Ireland), lowering the yield. On the whole, one would expect freedom to combine subjects or to change the route within S&T would improve the yield. Indeed in the UK, where there is relatively good degree of freedom, there is little drop-out. In Sweden too, students are given the opportunity to take breaks and they have great flexibility to change study programmes during the course of the study. However, Finland shows that more freedom need not result in a better yield; on the contrary, it may even fall. Students are free to follow any course once they enter university. This means that if students cannot get on their first-choice course subject, they can register for another less competitive one, e.g. mathematics or physics. Once in

they proceed to follow courses of their preferred subject and slowly drop out of S&T. This is reflected in the statistics on successful completion.

A second structural issue that can lower the yield is the **freedom (and the propensity) to work** during the study period. In Finland and Sweden this results in a low yield (or high drop-out rate). In Finland this aspect really reflects the ‘success’ of the S&T studies. Students in S&T tend to start working in their chosen occupation before graduation (part time or full time). Because of this ‘success’ students lack time to pursue their studies and either take a long time to graduate or even drop out. This reflects negatively on student retention. In Sweden this occurs more outside S&T (humanities, social science and the like) and while it is not clear whether these ‘time out’ periods are used for working or other life-cycle activities, it does reflect negatively on student retention overall.

Finally, the **duration of an S&T education** can influence retention levels. The hypothesis here is that a longer period of study increases the chances of drop-out if other circumstances are equal.

Before the introduction of the BaMa system in 2003, the Dutch higher education system was characterized by a nominal duration of four years for all studies, with S&T disciplines usually taking a year longer on average. From 2003 onwards, the system has become somewhat similar to the British system, with a three-year bachelor’s cycle followed by a two-year master’s cycle at university level, and vocational routes leading to a bachelor’s degree after four years.

In all six countries an MA requires between five and seven years, with an average of six years. In Finland and Sweden, however, students can take substantially longer. This is not due to the quality or the difficulty of the courses, but a result of suspending studies for work or other reasons.

In Ireland, there are three options for vocational as well as higher education. A bachelor’s degree takes about three years, but some require five and medicine takes six years. The degree is sometimes followed by post-graduate courses. In the UK, undergraduate courses require three years for non-S&T and a year longer for S&T subjects. Medicine and veterinary medicine extend to six years. A master’s degree requires an additional year or sometimes two, resulting in an expected duration for an MSc of five to six years.

In Germany, there is a difference between universities – with a duration between five and seven years – and Fachhochschule (for the more applied subjects), which require on average four-and-a-half years.²⁴

In Finland, the official duration of tertiary education varies by faculty. All students get about 55 months of support, with an option for an additional 5 months for technology students. This would seem to indicate that the normal maximum would be somewhere between five and six years. In Sweden there is a somewhat similar situation. The duration of tertiary education is linked to specific time frames – diploma in two years, a bachelor’s in three, a master’s degree in four years, and various professional degrees in one to five-and-a-half years depending on the discipline. However, as students are free to take extensive breaks from their studies, it is difficult to calculate the average duration of a degree. Estimates indicate that about 60% of students complete a degree within ten years (Salerno, 2003). The average length for a doctorate is six to seven years, with students in science, medicine and agriculture finishing in six. Breaks seem to occur more in social sciences and humanities, where the average completion time is around ten years.

In Italy, there are no differences in the duration of S&T and non-S&T studies: a basic undergraduate degree (Corso di Laurea) requires three years; an advanced undergraduate degree (Corso di Laurea Specialistica) needs two additional years. Students who have successfully

²⁴ http://www.rwth-aachen.de/zentral/english_TH_allg_guide4.htm

completed a Corso di Laurea can access a First-Level Master's degree, but only after a Corso di Laurea Specialistica can they pursue a Second-Level Master's degree, although this programme is not yet in place.

Labour market position of S&T graduates

There is anecdotal evidence that provides insight into the importance on study choice of how the future labour market position is perceived. An Irish survey (quoted below, p.43) examined the reasons why new students chose a career in S&T. It appears that the main reasons were:

- a strong interest in the subject and in a career in S&T;
- perceived job availability;
- salary.

The main reasons for students *not* to study S&T were:

- the comparatively long duration of an S&T study;
- a lack of interest;
- perceived job unavailability.

The Forfás report describes how students may choose between different (S&T or other) subject areas:

“Although certain SET professions are well paid, graduates continually search for best opportunities. This manifests itself in the migration of SET graduates to non-SET professions. [...] When comparing the starting salaries for these non-SET professions with the average SET starting salary, it is evident that the average SET starting salary is very competitive [...]. If migration to non-SET professions occurs in spite of a competitive starting salary in the SET area, then it is most likely that other career-associated factors are influencing the career decision-making process. [...] Migration of science graduates from SET to non-SET areas can be viewed in a positive light because it demonstrates that SET skills are adaptive, flexible and relevant. It might also be expected that the presence of SET skills in non-SET professions would create a more positive attitude in society towards SET in the longer term. However, this outward migration pattern runs counter to the increasing demand by industry for science skills and the reasons for this migration should be investigated.” [Forfás 2003]

Perceived job availability is not the most important driver of study choice, but it is second only to interest. The question is whether these perceptions are substantiated by the actual job availability for S&T students. This section provides information where available about the employability of S&T graduates in the surveyed countries. In this discussion we address employment and demand for S&T graduates and professionals, and as far as data is available, we discuss career choices, and development and income.

Employment

In general, the labour market has improved between 1980 and 2000. Germany is an exception, burdened as it is by the problems of reunification and slow economic growth. Table 5-2 provides a summary comparison of total unemployment and youth unemployment in the sample countries.

Table 5-2
Unemployment in the comparison countries, c. 2000

	total unemployment 2002 (% of the civilian labour force)	youth unemployment rate, under 25 2002 (% of the youth labour force)
Finland	9.1	20.7
Sweden	5.1	12.8
Ireland	3.7	7.7
Italy	9.6	26.3
UK	4.8	11.0
Germany	7.9	9.7
<i>Netherlands</i>	<i>2.7</i>	<i>5.9</i>

Source: OECD, *OECD in Figures 2003*.

In terms of unemployment, Finland, Italy, and Germany stand out: all have comparatively high unemployment rates, while Finland and Italy have a remarkably high rate of youth unemployment. Ireland and the Netherlands are the most successful countries in employment, which may be considered remarkable given that they also have the highest rate of population growth.

There is comparatively little information on the employment status of graduates from higher education. Labour-force statistics generally show the structure of the labour force by the highest level of education, but they do not show employment by field of study.

Table 5-3
Cohort analysis of the employment status of *laureati* by field of study and gender in Italy, 1995-2001 (%)

	cohort 1998 in 2001			cohort 1995 in 1998			cohort 1992 in 1995		
	men	women	total	men	women	total	men	women	total
S&T									
not working but looking for work	3	7	5	8	18	11	9	13	11
not working or looking for work	6	10	8	3	6	4	4	5	4
total unemployed	10	18	12	11	23	15	14	18	15
non-S&T									
not working but looking for work	15	16	16	31	32	31	28	27	27
not working or looking for work	35	20	23	12	7	8	19	10	13
total unemployed	50	36	39	42	39	40	46	37	40

Source: Annuario Statistico Italiano.

For Italy, there is a cohort analysis of the employment status of former higher education students three years after graduation. An analysis of the data in Table 5-3 leads to three conclusions:

- Unemployment is considerably lower among S&T graduates than among the graduates in other fields of study. The unemployment rate of male S&T graduates has fallen since 1995 unlike that of female graduates.
- The level of unemployment in 2001 is similar to that in 1995, but a larger proportion is no longer looking for work. This may suggest that there is a structural lack of demand in the labour market. If it does, then the data suggests that there is no real lack of demand for S&T graduates.
- Women who have studied S&T are more likely to become unemployed than men, but among non-S&T graduates a larger proportion of men is unemployed (and not looking for work).

Employment information for Ireland can be used for a similar analysis. The data in Table 5-4 confirms the long-term decline in unemployment in response to the continuing growth of the Irish economy. However, quite contrary to the Italian data, in Ireland the percentage of graduates seeking employment is somewhat higher in science and engineering than in most of the other groups. The percentages are, however, low and the overall Italian situation is much worse than that of Ireland.

Prospects for S&T professionals are generally good. In Ireland, employment levels have risen by more than 50%. The shortage of skilled S&T professionals – brought about by declining cohorts of young people – was met by an exceptional increase in female labour participation. There is a constant demand for S&T professionals, but many (about half of all graduates) move into business and the financial industry where wages are better.

In Finland, unemployment among higher education graduates is considerably lower than the overall level (9.1%) at, on average, 3.5%. The unemployment rate for professionals with a technological degree is a third of that for professionals with other degrees (1.3% as against 3.9%). Unemployment for professionals is low in the UK at only 2%, against 4.1% for all people. In Sweden the number of S&T graduates is not expected to be sufficient to meet demand (NIFU, 1998; Ministry of Education and Science, 2003c). This means that these graduates will have a strong position in the labour market (NAHE, 2003a).

Table 5-4
Proportion of graduates with primary degrees seeking employment in Ireland, 1995-2000
(%)

faculty	1995	1996	1997	1998	1999	2000
arts and social science	5.0	4.4	2.3	2.4	2.5	2.3
science	3.8	3.5	2.2	2.6	1.6	2.6
commerce and business studies	2.3	2.6	1.6	1.5	1.3	2.2
medicine, dentistry and paramedical studies	0.5	-	0.8	0.4	1.0	0.2
engineering	4.9	3.6	2.1	3.1	1.6	1.8
law	2.5	2.1	1.1	1.1	0.4	0.4
agriculture	0.9	2.1	1.3	2.1	2.6	2.9
architecture	1.9	4.0	1.4	-	-	1.9
food science and technology	4.7	7.3	4.3	3.0	-	7.0
all faculties	3.8	3.4	2.0	2.1	1.8	2.1

Source: Higher Education Authority, *First destination of award recipients in higher education (2000)* (Advisory Group on Labour market Trends; January 2002) p. 20.

Demand for S&T

In general the demand for skilled professionals, in particular for S&T, has increased over the last few decades and is expected to rise even further.

The UK, Sweden, and Finland seem to be able to meet current demand. However, in Sweden and the UK there is real concern about the future. The demand for S&T graduates in the labour market is so high in the UK that it has become increasingly difficult to retain them for R&D. In Finland, discussions about possible future shortages have been replaced by concerns about sufficient job opportunities for S&T graduates. Since the burst of the IT bubble at the end of the 1990s, Finland seems to be capable of meeting its demands for S&T graduates.

In Germany, there seems to be sufficient supply, particularly from a large pool of experienced S&T professionals. This pool, however, is not used to balance the market. In Ireland, there are not enough S&T graduates, a problem that is exacerbated by the fact that about half of these graduates choose a more profitable career outside S&T.

Career choice and development for S&T

A persistent problem is the mismatch between study and employment. A large proportion of S&T graduates appears unable to find a matching job. Germany has even developed a special work permit to recruit professionals from other countries rather than to try and counter the problem domestically.²⁵ The mismatch between demand and supply is less urgent in some countries than in others. Table 5-5 presents international estimates of the degree to which graduates find the kind of work for which they have been trained. In general, technology graduates are more likely to find such work, presumably because their training is more closely aligned with the practical application of skills. However, science graduates are between 10% and

²⁵ <http://www.goethe.de/kug/buw/fut/thm/en55917.htm>

25% more likely to find work outside the domain of their training, and will build more on their generic capabilities.

In Germany, the educational system, particularly the technological areas, is somewhat rigid and gives access to specific career options concentrated in specific industries and research. In Finland, many graduates flow into industrial R&D, with Nokia as a leading representative, and large numbers pursue a career in teaching or research at universities and polytechnics. Up to 90% of university graduates end up in specialist occupations. In Sweden, S&T graduates flow into teaching, S&T-related occupations and engineering.

In the UK, the choice is very open, from work in academic research and private organisations to careers that lie outside S&T. More than half of physics, engineering, chemistry and computer science graduates continue in business manufacturing and R&D. About one in four mathematics graduates pursues a teaching career, making this the second most chosen career; about one in ten of

Table 5-5
Percentage of graduates that finds a job
outside the domain of their education (%)

	science	technology
Italy	68	43
Greece	63	37
Sweden	60	24
Austria	56	24
France	53	28
Slovenia	50	23
Spain	48	26
Belgium	44	37
Hungary	44	27
Finland	43	23
Denmark	36	26
<i>Netherlands</i>	<i>50</i>	<i>23</i>

Source: EUROSTAT, "School leavers in Europe and the labour market effects of job mismatches", Statistics in Focus, theme 3 (5/2003).

the other S&T graduates make the same choice. The pull of the financial sector here is much lower (approximately 5%) than in Ireland, where, as mentioned before, about half of S&T graduates flow into business or financial industry. In Italy, industry is more production-oriented and a PhD can be an obstacle rather than a benefit in finding a job. In general, applied S&T graduates, engineers in particular, flow into industry fairly easily (about 80% get a job within one year) and from there into management positions. More scientifically oriented graduates can turn to universities, but the employment opportunities are not very good at the moment. However, from 2010 onwards this should change dramatically due to 'mass' retirement.

Income development for S&T

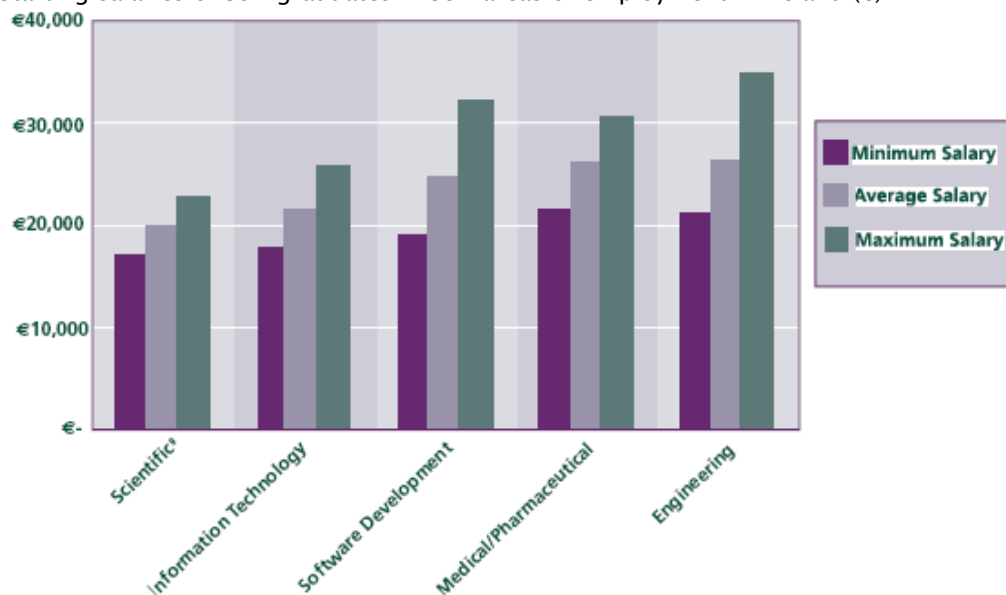
There exists very little hard data on income. Statistical data on incomes in Italy seems to confirm the opinion expressed in interviews that skilled S&T professionals earn somewhat higher salaries, but the data is anecdotal. In Finland, the average annual salary of technically skilled professionals appears to be some €12,000 higher (about 33%) than that of professionals with other university degrees.

In Ireland, the starting salaries for S&T graduates are generally higher in S&T areas of employment than in the alternative areas such as logistics or financial services. Only in general scientific functions are salaries lower than in alternative employment opportunities. Information technology, software development, medical and pharmaceutical work and engineering are financially attractive (Figure 5-4). Only in consultancy do graduates have a better chance of getting a higher salary than in the S&T sector itself (Figure 5-5).

The data for the Netherlands shows that salaries in S&T differ by profession and level (university vs. polytechnic/vocational). In general, jobs in agriculture, environment, food technology and laboratories are seriously underpaid. At university level, mathematicians and scientists (chemistry, physics, etc.) are on average also underpaid, while salaries in engineering (civil, electro- etc.) are on par with other salaries. Polytechnic graduates in information science and chemical technology are relatively well paid.

Figure 5-4

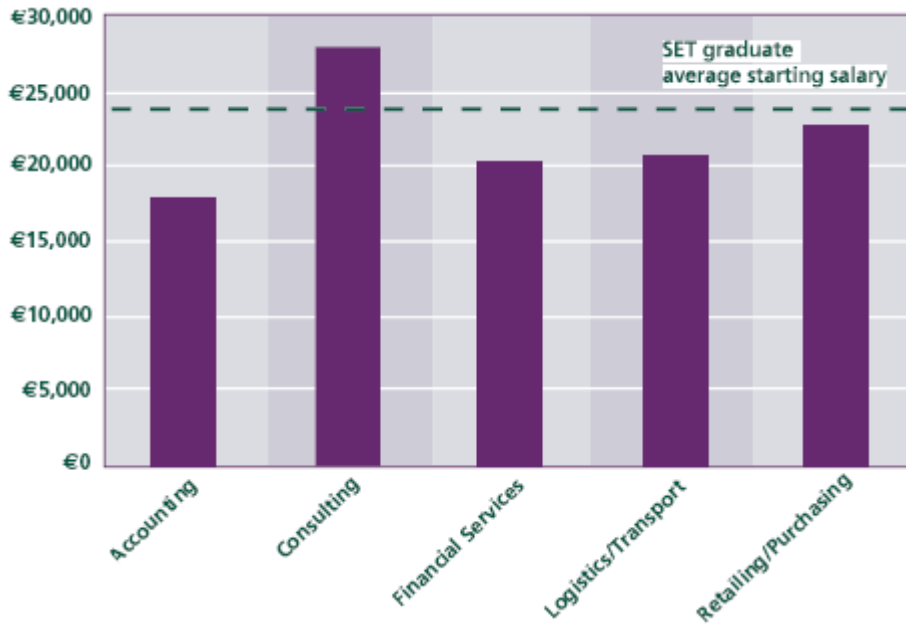
Starting salaries of S&T graduates in S&T areas of employment in Ireland (€)



Source: Forfás, *A Comparison of Starting Salaries for Science and Engineering Graduates* (ICSTI Statement; June 2003)

Figure 5–5

Average starting salary for alternative professions pursued by S&T graduates in Ireland, 2001 (€)



Source: Forfás, *A Comparison of Starting Salaries for Science and Engineering Graduates* (ICSTI Statement; June 2003)

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Conclusions

Yield of higher education

While the relative numbers of S&T graduates in the Netherlands, Ireland, the UK, and Sweden are similar compared to the overall numbers of graduates, the Netherlands produces considerably fewer S&T graduates for the labour market than other countries. Finland, the UK and Germany have a relatively high share of S&T graduates among total graduates, while the UK has a high share of S&T graduates in the total age group of 20–29-year-olds.

The structure of higher education could, in principle, influence the output to a considerable degree. However, we have not detected specific factors that seem to affect the numbers in a specific direction in any of the countries. With respect to the nominal duration of studying S&T, there are no differences between S&T and non-S&T studies. Propensity to work can be considered lower in the UK and Ireland where a more class-like education is provided, and higher in Sweden and Finland where it is not. However, we have not been able to detect a relationship between higher propensity to work and lower graduation ratios, even though this is considered to be a factor for lower graduation rates in Finland. Compared to other countries, this observation is difficult to support. Finally, freedom of changing studies could help explain a higher S&T drop-out rate in Finland, as students use easier access requirements for S&T studies to enter other disciplines. However, data cannot support such observations in other countries.

Labour market position

The employment situation of S&T graduates varies across countries. In general terms, it can be stated that higher education provides much better employment opportunities than non-higher education. S&T graduates are not necessarily better or worse off than non-S&T students. Most striking, however, is the considerable migration of S&T graduates to non-SET professions.

Finland is an exception in which S&T graduates have better opportunities for higher paid work and remain working in the S&T sector as well. The high number of graduates here would seem to indicate that the overall demand for S&T in the economy is very high.

The analysis described in chapters 3 to 5 has shown that the last twenty years have by no means witnessed a general boom in S&T in higher education. The experiences of the six comparison countries and the Netherlands vary considerably. Some countries have clearly forged ahead, while others are in danger of falling behind. Using the data on the share of new entrants, enrolled students, and graduates in higher education in S&T, and on the share of women in the S&T student population, we have classified the countries into four groups: 'Forging further ahead', 'Losing momentum', 'Catching up', and 'Falling further behind'.

Finland is obviously the best performing country among the seven: it is either forging ahead or catching up. Sweden appears to perform almost as well. The Netherlands, on the other hand, is at the bottom of the group and policymakers seem to have every reason to be concerned. Among the remaining countries, Italy and Germany have not been able to copy the Scandinavian performance, while Ireland and the UK may have reached their peak and are now losing momentum.

In addition, we have compared the relative performance of the seven countries in five domains: economic growth, demographic growth (including the potential future supply of students), benchmark estimates of S&T in higher education in 2001/2, the rate of growth of the student population in S&T since 1990, and the situation on the labour market (total and youth unemployment).

This comparison confirms the good performance of Finland and Sweden and the slight lag of Ireland behind the Scandinavian leaders. The UK still performs relatively well. However, with a few exceptions (such as employment in the Netherlands), Italy, Germany and the Netherlands are consistently behind the leading countries.

Policy developments: trends and types of measures

Both the status and the structural aspects of the education systems in the six countries surveyed differ quite considerably. A main focus of this study is to establish whether governments have developed specific policy measures in the past decade to change the structures and/or attempt to influence the status of S&T in higher education. We selected the most prominent measures in each country.

The relevant policy measures found in the six case study countries were organized in a number of different ways. In this chapter, we have grouped and presented them by the various factors that influence the choice for a particular field of study. Subsequently, we look at the types of policy levers used, such as financial, regulatory or information provision. Finally, we have made an inventory of the effects and effectiveness of the policy measures selected. An overview of all policy measures analyzed – chronologically by country – is included in Appendix A.

Policy developments in the last decades

Finland, the UK, and to a lesser extent Ireland, are countries which realized relatively early that some intervention with regard to S&T was necessary. Sweden followed in the early 1990s, when it formulated the major goal of HE as “equality of the sexes, place of residence and social and economic circumstances” (Ministry of Education and Science, 2003a). Italy and Germany are relative latecomers to policy development for S&T, with all initiatives dating back only a few years (1999/2000).

On the whole, there is no evidence that large shifts of priority for education have occurred following political developments. On the contrary, education is usually perceived as a clear priority by all types of government. In the UK, both the Labour and Conservative parties released reports and white papers, which built on each other’s positions and showed no shifts in priority or goals.

However, there is a difference in how new policies are implemented. In some countries, education is more or less centralized in the sense that there is national legislation or set of standards that can be ‘imposed’ on educational institutes (e.g. Netherlands, Sweden and, to a certain extent, the UK). In this context it is easier to control the comprehensiveness of the implementation, although even then the results may be a long time in coming (Ireland). In countries where regions or institutions have a relatively large measure of independence (Finland, Italy and Germany), compliance to policy or reform is more difficult to control.

In Finland, the government encourages regional development, which has resulted in many educational institutions competing for students. In this environment, it is in the institution’s interest to implement improvements as soon as possible. In Italy and Germany, where institutions are relatively free in choosing how to implement regulations, institutes can either stay rather insular or increase local cooperation (Italy).

The major focus areas in policy development are on

- Access and enrolment:
 - Improving access to S&T education and increasing S&T uptake and enrolment in HE.
- Quality:
 - Improving the quality of S&T education
 - Reforming the curriculum to meet better student preferences and expectations
 - Encourage an interdisciplinary approach
- Specific groups:
 - Encouraging women to choose S&T or to retain existing female S&T professionals
 - Encouraging the participation of less privileged, ethnic and other minority groups in HE
- Improve student retention of S&T
- Labour market:
 - Encourage S&T as a career
 - Industry involvement
 - Immigration and remigration of professionals to meet the demand

Many policy measures do not uniquely focus on individual elements, as listed above. Many include multiple aspects, either as the principal or the secondary aim of policy. This is the case particularly for the more comprehensive initiatives such as LUMA or those that deal with curriculum reform. As a result, a number of initiatives are mentioned under more than one heading in the following paragraphs.

Improving access and increasing enrolment

Enrolment in S&T

In Finland, improving access and increasing entrance to HE is an important issue. It first targeted access, initially by facilitating standard requirements (1974), then creating alternative routes (1988, see the section on targeting specific groups) followed by reforming the entire technical side of HE by creating a large number of polytechnics throughout the country (1990), improving S&T education at all levels (LUMA 1996) and creating more dedicated study places (e.g. IT-related industry intake, 1998).

In this review, the creation of the common admission requirements for an MSc in Technology and Architecture (Finland, 1974) is the oldest measure aimed at increasing access to tertiary level. At first this initiative was implemented at only seven institutes in Finland, and aimed to standardise admission requirements, making it possible to enrol at more than one institute, and to facilitate a more efficient entry procedure. This successful initiative has since been copied (by other institutes and in other subjects), and many other similar initiatives are now active within Finland.

The Leaving Certificate Vocational Programme (LCVP) in Ireland is a typical example of increasing enrolment by creating alternative routes into higher education. By tailoring the curriculum towards more applied and vocational technological routes, access to S&T was generally improved. Headstart in the UK (1991) is another initiative that helps access (and presumably also yield) by increasing informed choice among groups already interested in S&T. In Sweden the creation of the SciTech Basis Year has improved access for many graduates from secondary education who change their career plans towards S&T (OECD, 1997).

The Bildungskredit in Germany facilitates access for less affluent students, but it can also increase student retention by preventing drop-out for financial reasons.

Shift towards S&T

In Sweden, measures are aimed all three levels of education (from ISCED level 1 to 6; OECD, 1997). The measures aimed at primary and secondary education often target teachers and are meant to promote modern, high-quality S&T teaching (NOT or SciTech, since 1993) under the premise that this will eventually result in higher uptake later on in the educational system. In addition the SciTech Basis Year (1992) targets pupils leaving SE who lack sufficient S&T skills. These students are offered an additional preparatory year before enrolling in the first year of HE, thus creating a 'second chance' to choose S&T. This measure in particular has been evaluated as highly successful.

Finland has implemented measures from 1974 onwards, many aimed at increasing or improving S&T enrolment. A large set of policy measures under the national policy umbrella of LUMA focus on improving S&T education and dissemination of best practices. Many of these LUMA measures are aimed at S&T education at primary and secondary level, focusing on curriculum reform, increasing S&T teaching skills in the existing teaching corps, and upgrading entry requirements with regard to S&T skills in teacher training. As in Sweden, the assumption here is that if S&T education is improved from primary level upwards, not only will science literacy within the general public improve, but it will also eventually lead to higher enrolment and better results in higher education S&T.

In Italy the focus of increasing S&T enrolment is placed on increasing cooperation and communication between institutes for secondary and higher education. In this way science education at secondary level will improve, which in turn will lead to more pupils interested in S&T, a larger uptake at secondary level and a shift towards S&T in higher education too. The Women in Engineering Professions initiative (2002), is more localized and offers grants to around 200 women students each year for additional tutoring in S&T subjects to encourage female enrolment in engineering.

Improving quality of S&T and curriculum reform

Quality of S&T

In all six countries there have been initiatives to improve the quality of S&T, sometimes from primary level upwards (Finland, Ireland, Sweden).

On all levels: In Ireland the issue of access was, in fact, an issue of improving the quality of S&T education. The initiative took the form of a wide-ranging curriculum reform (starting in 1985) aimed at increasing practical work in S&T. This Chemistry and Physics Intervention Project was followed up by the Task Force on Physical Science in 2000. The latter initiative specifically targeted the uptake of S&T (also at a primary level) and emphasized the priority of S&T within schools, resulting in a clear place for the subject in school management, the involvement of stakeholders, and a more practical orientation.

In Sweden primary- and secondary-level science teachers are supported through National Resource Centres, specifically aimed at increasing skills and competencies of science teachers. The NRCs started in 1994 (for chemistry) and were followed up by 2002 (for biotechnology).

In Finland, the creation of the polytechnics opened the way for considerable upgrading of teacher requirements and quality improvements. Many initiatives included in LUMA (1996 and onward) covered curriculum reform and enhancing the quality of the curriculum, of assessment and of teacher training. A central theme in LUMA is the dissemination of good (teaching) practices. Developing communication between the education and industry sectors to improve the match between skills and demand is an additional target.

Secondary upward: Countries focusing more on secondary and higher education are Italy, the UK and Germany. Efforts by Germany to make science more interdisciplinary do not seem to have been successful, but no official evaluation is available. Italy aims to improve science education by encouraging interaction between secondary and tertiary levels and between industry and higher education to help bridge the gap.

Part of the SETNET initiative in the UK covers curriculum reform as well. However, the Student Associate Scheme (SAS) has a more direct impact on the quality of S&T by lowering the teacher-student ratio. In the SAS, students experience teaching as an assistant to experienced teachers, which opens their eyes to a career in teaching, as well as supplying role models to pupils.

Curriculum reform and student preferences

In Ireland curriculum reform was initiated to improve the image of science in upper secondary school (Chemistry and Physics Intervention Project, 1985). In this instance the curriculum was reviewed, more practice-oriented courses were introduced, and grading principles as well as the type of assessment were modernized. The reform was general but had an emphasis on creating a style of science education that might attract more girls. The Leaving Certificate Vocational Programme (LCVP) is another Irish initiative, which tailors the curriculum towards 'learning by doing', thus targeting a specific type of student.

In Finland, a number of curriculum reforms were implemented, without taking specific student preferences into account *per se*. MIRROR (in 2002) was an example of reform of S&T education specifically for the benefit of female preferences.

The creation of the SciTech Basis Year in Sweden can also be seen as an example of this type of policy measure, because it creates an intermediary year to meet students' needs and preferences, allowing them time to change courses, and giving them alternative routes towards a course or career in S&T.

Encouraging crossovers and interdisciplinarity

Facilitating combinations of studies or initiating multidisciplinary courses is another way to increase S&T literacy and awareness throughout the population. In some countries this multidisciplinary has been the specific focus of policy initiatives (IDBM, Finland). Furthermore, initiatives have focused on inserting S&T characteristics in non-S&T programmes such as the IT-related Temporary Upgrade Programme (also in Finland). Most recently, Finland has also fostered a system in which courses are combined between universities (2004). Earlier in the chain (primary and secondary level) Sweden has developed the multidisciplinary approach of SciTech to improve the image of S&T among children under 16 years old.

Targeting specific groups

In these initiatives, three student groups have been identified, which have required specific measures: women in S&T, students from low-income backgrounds and mature students. Regarding the latter, the policy is not aimed at a particular age group, but at increasing attendance levels in higher education for all cohorts, and at enticing relatively young people who have not entered higher education to do so at a later date.

Women and S&T

Gender, and gender shifts towards S&T, have become policy priorities in the mid 1980s, when Ireland implemented curriculum reform partly to increase female participation in S&T subjects at secondary level (1985), and the UK initiated an awareness campaign targeting women in

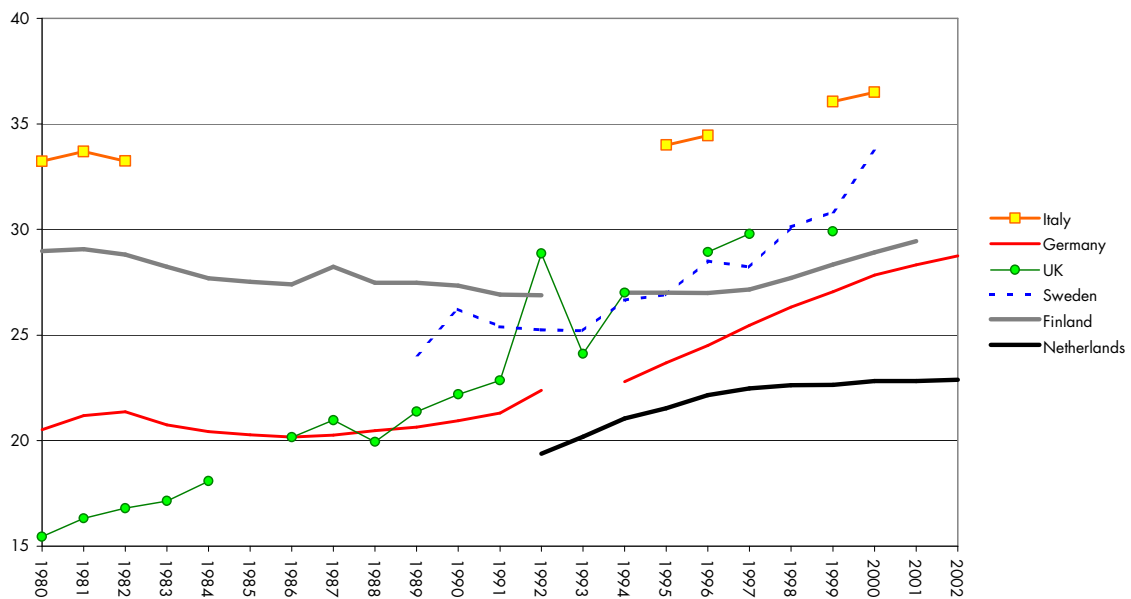
higher education (WISE, 1984). Finland followed a few years later with the creation of alternative access routes into S&T at tertiary level by implementing special admission requirements at Tampere University of Technology at most of the engineering programmes for students with inadequate mathematics (1988). This measure was created to increase overall enrolment, but as a secondary goal it aimed to increase female participation as well. A similar result can be found in Sweden, with the SciTech Basis Year (1992), which was aimed at overcoming insufficiencies in maths and science skills, and has led to increased female enrolment. The first Finnish policy measure solely aimed at increasing female enrolment in S&T (to 33%) was TiNA (2001).

Figure 6.1 below clearly shows that in Finland female participation has remained more or less stable (between 27% and 29%) for the last 20 years. This is remarkable because the earliest initiatives aimed at women date from 1984, and these do not seem to have had much of an impact, showing no clear upswing in female participation. In the UK and Sweden, however, which both started with a lower proportion, the initiatives seem to have resulted in significant growth. The WISE campaigns (1984) and its successors (e.g. PSETW in 1994) have been very successful, doubling the female participation in the UK in some 20 years. An important difference with the Dutch situation that comes to mind is the duration of the effort going into such campaigns. While in the Netherlands campaigns, such as ‘Kies exact’, have a relatively short lifespan and are then terminated or replaced by a different campaign, the WISE, PSETW and non-gender-related initiatives (SETNET, Everything you wanted to know) span much longer periods under the same banner – sometimes decades – and have been built upon over the years.

In Italy, female participation is relatively high, except in engineering; to address this Italy recently implemented the Women in Engineering Professions programme (2002). This relative lack of priority is also supported by statistics (Figure 5.1). In Italy the available data indicates that there is a relatively high proportion of females in S&T (around 35%), which has remained more or less stable in the last 20 years.

In Germany female participation in S&T has been increasing steadily over the last five years. It is remarkable that in Germany, and to a lesser extent the Netherlands, female participation has also increased, despite the general decline in S&T within the student population as a whole.

Figure 6-1
The share of women in the student population in science and technology, 1980–2002 (%)



Other groups

In Germany and the UK there are policy initiatives to support students from **less affluent groups** in society. Germany, where students rely heavily on their parents for income, introduced the *Bildungskredit* in 2001, which is available for all students to prevent them from dropping out for financial reasons. In the UK, some 30% of the students are currently exempt from paying tuition fees and there are dedicated hardship funds as well. In the new system about to be introduced, there is a similar feature, where poorer students will not have to pay the basic fee, only any fee above that.

Policy measures aimed at increasing the education level in specific **age cohorts** have differing effects. For instance, increasing the maximum age (to 25) for admission to higher education in Sweden was designed to increase the proportion of people with degrees per age group, and it led to an increase in mature students. A similar result can be seen in the UK. However, the policy to increase the proportion of pupils entering higher education immediately after secondary education, as initiated in Ireland and Finland, has led to a general lowering of the average age.

Improving yield

Yield (or student retention) is defined here in a more or less statistical way; it is the proportion of entrants who graduate in S&T-related subjects.

The initiatives to standardise entry requirements in Finland were also aimed at selecting good applicants to improve student retention. Headstart in the UK is a programme aimed increasing the likelihood of ‘the right’ choice, by supplying pupils interested in S&T with extensive additional information on their options through a summer-school programme. A less labour-intensive initiative in the same vein is the website (and brochure) of ‘Everything you wanted to know’ which provides information on financial support and work opportunities in S&T. The underlying assumption here is not only that better information might increase uptake by good students, but also that financial information might help prevent drop-out for financial reasons.

Preventing drop-out is a direct way to improve yield and in Finland they have created the Graduate! initiative that helps S&T students (in particular in engineering) who are in danger of dropping out due to lack of time. Graduate! provides information, networks and personal mentoring to facilitate graduation. The *Bildungskredit* in Germany – aimed at students who do not receive general support – is also specifically aimed at preventing drop-out due to financial hardship.

Labour market initiatives

Encouraging S&T careers

There are also two basic ways to encourage S&T careers: providing information on opportunities – sometimes supported by role models – and providing a financially and intellectually competitive S&T working environment. Policymakers have explored both options. Often initiatives aimed at increasing uptake focus on giving access to information options in S&T, establishing role models, or providing S&T workplaces and opportunities for S&T careers.

An example of this development can be seen in the UK, especially in the policy measures aimed at gender inequality in S&T (STI Outlook, 2002). These measures started with WISE (in 1984), which has since been based on facilitating information access through websites, brochures, courses and presentations. With the PSETW some ten years later, personal mentors and role models were introduced while information was tailored to different age groups. The British

SETNET initiative is a successful example of providing role models, such as the Science and Engineering Ambassadors and the Science and Technology Ambassadors, who have current information on industry developments at their fingertips to promote S&T careers. The most recent UK initiative, Athena focuses on increasing the number of women following a career in S&T.²⁶ It includes financial incentives and earmarked funds to provide a better working environment for women in S&T.

Policymakers have also identified quality of teaching as an important driver to increase the uptake. At the same time, S&T teaching skills have often been found to be inadequate, a situation aggravated by the insufficient inflow of new, well-trained science teachers. The SAS initiative in the UK is specifically designed to address this issue: by exposing S&T students and graduates to the practice of teaching, they are encouraged to consider it as a career.

Many countries have now implemented policies to improve working environment and opportunities in S&T research. Usually this involved freeing up earmarked funds for S&T research places, either for

- (post) doctoral students, by creating research places or fellowship posts (Finland, the Graduate! school system; Ireland, post-graduate stipends and salaries; Italy, Decreto 279-99; UK, Investing Human Capital);
- specific groups (women in the British ATHENA Programme; in Finland, the IT-graduate school positions);
- post-doctoral research, by the creation of junior professorships (Germany; UK, Investing Human Capital); or encouraging R&D in private industry (Italy, Decreto 279-99);
- more permanent improvements in salary to counter the brain drain towards other professions (in Ireland) or other countries (Italy).

Initiatives from industry

In all six countries, future S&T-oriented employers have taken initiatives towards S&T students and graduates.

In some instances the initiatives are based on information access and promotion. Such initiatives can be found in Finland (with the Association of Graduate Engineers, TEK), Italy (cooperation between industry and institutes for higher education), and the UK (the creation of the ETB creating a unified platform in partnership with industry and business). One of the earliest initiatives is the Finnish TEK Recruitment Service (since 1986): a free-of-charge service enabling an efficient marketplace for S&T graduates.

In others, industry is actively involved in the educational process through the creation of new courses (Ireland), sponsoring of professorships and research places or grants (Finland, Germany, Italy), or encouraging cooperation between universities and industry integrating university research with big and small industrial R&D (Sweden, VINNOVA and VINST).

Immigration and remigration

A number of countries have taken measures to make immigration for specific groups easier. Germany has created the 'Green Card' (in 2000) to facilitate active recruitment of foreign specialists, which has led to an influx of Indian nationals, and a significant drop in IT-related vacancies. Ireland has taken a similar route, creating the Worker's Visa (for IT professionals, technicians and so on). Ireland also follows an aggressive policy of attracting leading scientists, but the fear is that they will leave after their contract period.

²⁶ <http://www.eteachb.co.uk/campaigns/athena.asp>

In the UK, they have now amended immigration law for skilled professionals, by dropping the entrance requirement of already having a job (Highly Skilled Migrant Programme, 2002). This means professionals can enter the country first, and then start looking for a position later. In Sweden, foreign experts employed in Sweden are given a three-year tax reduction. The exemption is only available for highly qualified and uniquely skilled experts (STI Outlook, 2002).

Italy and Finland do not have specific initiatives to encourage immigration, but the process can be speeded up in Italy. Finland has a sufficient inflow of foreign scientists due to the attractiveness of high-tech industry (in particular, Nokia) and does not require active recruitment at this time.

Policy measures by type

In this study we have discerned three types of lever through which policy can influence developments. These levers refer to the basic character of any measure – that is, whether it is of a facilitative, regulatory or financial nature. This study has shown that it is not always easy to place an initiative into only one category, especially large-scale initiatives, such as the creation of polytechnics in Finland, or the comprehensive LUMA programme which contains elements of all three. Such measures combining two or even all three aspects often try to capitalise on the direct, as well as the interactive, effects of the levers.

In Table 6-1 below, the measures selected in this study are listed chronologically per country, and categorized according to its nature: facilitative (Fac), regulatory (Reg) or financial (Fin) as well as for goals and target points (e.g. educational level, gender shift, labour market etc). It must be stressed that not all the policy initiatives regarding education are included here, but only the most relevant for S&T education and employment.

The German measures selected concentrate on financial or regulatory aspects and are not specifically aimed at S&T enrolment. The Swedish measures, on the other hand, are not aimed at financial incentives or on setting aside large funds to create study or research places, but on creating alternative routes and improving the quality of teaching. Ireland and the UK seem to have followed a more ‘Swedish’ route, first concentrating on improving quality through facilitating and regulating change. Both countries have more recently included a purely financial measure, increasing stipends and salaries.

The wide selection of Finnish policy measures indicates the high priority that Finland has given to issue of S&T literacy and its pervasiveness in society and the educational system. Finland has designed and implemented a very comprehensive set of initiatives over the past few decades, some of which were initiated ‘bottom-up’ by the universities (Common Entry Requirements), some ‘top-down’ by the government (polytechnic reform) and some initiated and largely paid for by industry (IDBM). It is remarkable that many of the measures are aimed at improving the match between skills taught and the demand from industry. Even the polytechnic reform was in essence ‘demand driven’; the involvement of the industry itself is a prominent characteristic in the ‘Finnish model’. Another characteristic is that many measures are either implemented locally (e.g. TiNA at only one institute), or that a national policy facilitates the implementation of measures ‘custom built’ for every school, institute or region.²⁷

The UK has also implemented a large number of measures, many of which seem to be aimed at creating a change in attitudes, to improve working conditions for women in S&T, and to encourage women to take up S&T as a discipline or career.

²⁷ Thus effects will not very often translate to a national trend and so the effectiveness cannot be corroborated using statistics

In Table 6-1, we have included additional information indicating what a measure is primarily designed to influence. The data also supports the impression that Italy and Germany have not yet started focusing on S&T as a priority area for policy development and are only just becoming concerned about it. In addition, where Germany still focuses on tertiary and higher levels of education, Italy has recognized the need to look at lower levels too in preparing for the future of S&T. As said, statistics do not prove them wrong in generally ignoring this issue; in both countries S&T uptake is not particularly low.

All countries, except it seems Sweden, have initiated multiple policies aimed at the S&T labour market. UK is unique in addressing the issue of barriers for women already in S&T careers and actively trying to preserve this resource by increasing awareness of biases and obstacles, as well as supporting women in their career development. In Finland, many of the initiatives are driven by the wish to improve the match between skills learnt and skills required in industry. Even the Polytechnic reform was in part a result of this: industry needed technicians with higher-level skills than were graduating from the existing vocational programmes. Initially it was expected the vocational programmes would co-exist with the polytechnics, however in many cases the polytechnic replaced the lower level courses.

Country	Measure	Fac	Reg	Fin	Aware ^a	Enrol ^b	Qual	Choice	Educ. Level ^c	♀	Yield	Labour ^d
	Investing Human Capital			-					D			PostDoc
	Student Associate Scheme	-			-		-		TE			Educ

Shading indicates which characteristics apply

***) Universities standardised entry exams; ^a) +attitudinal change; ^b) S=science, T=Technology, A=Architecture, C=construction, Voc=Vocational ^c) P=primary, S=secondary, T=tertiary, D=post-doctoral E=teachers; ^d) Res=Research, Educ = Education; -> = towards

Finland and Sweden are remarkable for not including any migration-related policy measures. The four other countries in this selection have at least one measure aimed at simplifying immigration or remigration of highly skilled professionals, including scientists and IT experts. While Finland and the UK target women specifically, in the other countries gender effects are recognized but not included as principal aims of policy. A higher uptake by girls resulting from a curriculum reform (e.g. in Ireland or Sweden) is perceived as an additional bonus.

Evaluation of policy effects

The aim of the current study was to identify effective policy measures. This implies that there is sufficient information regarding the effects of measures, for example through evaluations that include information on the change in uptake, yield, employability etc. This has not been the case. There are a number of reasons why the evidence required is not available, namely:

- some measures are very recent and no evaluation has been performed yet;
- an evaluation has not been planned or executed;
- the evaluation does not focus on measuring policy effectiveness, but consists of
 - an evaluation of the process (e.g. ‘schools need more time to implement IT’),
 - identification of success factors (e.g. ‘management support is essential’)
 - descriptions of best practices, without giving clear quantitative or qualitative data regarding the effect of the measure.
- the evaluation is of a anecdotal nature.

This issue is complicated further by the fact that when initiatives are very diverse or implemented at a relatively low level or small scale, for instance at the level of a single institute (e.g. TiNA in Finland), effects can not be determined using national statistics. Consequently, it is not always possible to identify effective measures and to quantify them.

In the Table 6-2 we have listed the selected measures by country, indicated the expected effects and evaluation results with key words and numbers. A more detailed description of the measures is included in the appendix B.

Table 6-2
Measures by country: expected effects and evaluation results

Country	Measure*	Expected effect	Evaluation
Finland	Common entry requirements	Quicker allocation of students	Doubled direct S&T entrants from SE
	TEK recruitment Admission Tampere Univ. of Techn.	Interactive market place Capture students with too little maths.	1,000 job seekers registered First dominated; now 50%/yr mixed
	Polytechnic reform Graduate School System (general and IT related)	Better quality skills More PostDoc places will increase pool and level	Better match between skills and demand More doctoral students; doubled number of graduates
	IDBM	Improve design business skills	More interdisciplinary graduates
	LUMA programme (all)	Better teachers better S&T	S&T uptake higher, good quality
	IT-related intake	More entrants->more outflow	Outflow up but lower than expected
	IT-related upgrade TiNA MIRROR	Encourage shift towards IT Increase to 33% in S&T Increase in S&T	Outflow up but lower than expected
	Association of Graduate Eng (TEK) Graduate! Flexible study right	Information will attract Eng. Personal support to help finish More combinations with S&T	
Germany	Junior Professorship Bildungskredit	Counter brain drain Counter drop-out for financial reasons	Summer 2004
	Green Card	Import will increase S&T base	15,110 Cards; 27% to IT, IT vacancies have dropped significantly
Ireland	Chem. & Phys. Intervention Project	Practical curriculum ->better S&T uptake	outperform , lower uptake Chem & Phys
	Task Force LCVP Work Visa Post-graduate stipend and salaries	Better image, better uptake Skills better taught in practice Increase skilled professionals Retain S&T PhDs and scientists	Immigration IT, construction workers, nurses
	IT-2000	ICT in school->higher quality	More time needed, good practices exist
Italy	SeT Decreto 279-99 Women in Engineering Professions Re-entry of Italian Scientists	Better quality->higher uptake Industry will create R&D jobs Tutoring ; more first years Tax relief: attracts top scientists	June 2004 260/yr granted; more requests
	Sweden	SciTech Basis Year	Catch up S&T skills->more S&T
Sweden	SciTech (NOT)	Increase uptake, 2 nd chance	15% increase, with 20% increase for
	NRC	Increase uptake S&T in HE	Seems to work better than expected
UK	WISE	Know the options->more S&T	in Eng doubled in 1984-2000
	Headstart	Informed choice-> less drop-out	88% say helps and 86% chose S&T first
	PSETW	Know the options->more S&T	Not received
	Specialist school programme SETNET	Focus improves quality Central contact improves access	Better grades for specialty; more courses SE Ambassadors are success; information access is good
	ATHENA	Awareness of gender differences will help improve career opportunities	Good practices identified;
	Everything you wanted to know? Highly Skilled Migrant Permit	Know the options->more S&T Simplify access -> more S&T immigration	Not well known; 90% is processed within 1 day; recruiting abroad is easier
	Investing Human Capital Student Associate Scheme	Improve S&T career competitiveness Experience as teacher-> more S&T into teaching	Pilot evaluated favourably

*) green = evaluation available, yellow = only anecdotal evidence

Which policy measures have made a difference?

We have already indicated that there is often insufficient information about the effects of measures, because many evaluations do not include information on the change in uptake, yield, employability and so on. We have examined various evaluation reports on policy measures implemented. Obviously, the effect and impact of more current initiatives included are as yet unknown and cannot be reliably assessed. In addition, we have contacted a number of experts in each of the countries (inside and outside of government) to get more additional insight into the effectiveness of these measures and policy developments.

It should come as no surprise that many evaluations come to the conclusion that the direct relationship between the policy and observed developments in S&T uptake (or whatever the focus of policy intervention was) in higher education is difficult to demonstrate fully. Nevertheless, there are a number of reports that hint at the positive influence of policy initiatives on their intended targets.

The existing data seems to indicate that

- S&T enrolment is positively influenced by measures aimed at
 - Creating a second chance to choose for S&T or to rectify insufficiencies in S&T skills (SciTech Base Year in **Sweden** and short intensive courses in **Finland**);
 - Offering more practice-oriented curriculum and vocational options (**Ireland and Finland**);
 - Improving S&T skills of teachers in SE and HE (**Ireland and Finland**);
 - Providing information (access) with regard to career options in S&T, supported by mentoring, role models (**Germany and the UK**);
 - Specialisation within disciplines (**UK**; Specialist Schools).
- Pursuit of an S&T career is positively influenced by measures aimed at
 - A more efficient match between labour market needs and S&T supply (Polytechnic reform and Graduate schools in **Finland**);
 - Creation of research fellowships, post-doctoral places and R&D in industry (**Finland, Germany and the UK**);
 - Improvement of salaries and stipends (**UK and Ireland**).
- Simplifying immigration procedures and offering financial incentives are successful in attracting foreign or ex-pat scientists and professionals to meet current demand.

These measures could be considered successful because they can help alleviate shortages in the labour market that would otherwise be difficult to improve by domestically oriented policy measures. In that sense, these measures could prevent sudden cyclical measures that might disrupt long-term investments in systemic changes.

Policy measures: how and why they seem to work

The previous chapters addressed the developments on the share of S&T students over the past decades, the underlying educational structures and the broad areas of attention in policy developments undertaken in the countries surveyed. This chapter expands on the previous analysis by combining the specific elements addressed in actual policy (such as changing the curricula in secondary education or providing more financial means for post-docs) and the various elements that have been considered crucial in academic and empirical literature for changing the S&T balance in tertiary education.

The various countries in our survey all seem to perceive similar problems with respect to the attractiveness of S&T in tertiary education, and their governments have targeted policy measures at a common set of bottlenecks that are impeding the desired flow of S&T students. The bottlenecks are also not necessarily dependent on the extent to which S&T enrolment or graduates is high or low. For instance, Italy and Finland still have measures in place that aim to improve the inflow of female students in higher education despite the fact that both countries have relatively and consistently high levels of female participation.²⁸

Based on the previous chapter, we can summarise that this common set of bottlenecks seems to focus on cultural and attitudinal (including the gender perspective) aspects, issues of quality of education and teaching, conditions relating to access and enrolment, and labour market perspectives. While policy measures might target the same bottlenecks independent of the numbers of S&T students in the country, the way in which countries have designed and implemented these measures are considerably different. The underpinning logic or theoretical explanation behind this common set of bottlenecks provides various incentives to think about policy implementation. Thus, this chapter will consider the connection between the detailed policy measures and the various aspects of the bottlenecks in order to assess the potential effectiveness of these measures and provide explanation to why they could be considered effective. In this chapter we discuss the four major dimensions that we have identified:

- changing attitudes;
- improving quality of teaching;
- influencing student retention;
- facilitating labour market conditions.

The first two dimensions focus on the issue of influencing choice in higher education towards S&T, and the latter two involve sustaining the choice made. In each of the subsections we cover related issues and empirical research, and comment on how policy measures in the review address

²⁸ In other words, while we can easily measure the level of S&T students and the like, it remains unclear what level is appropriate or good.

these issues. Much of the research quoted in this chapter refers to the S&T at a tertiary level, including universities and polytechnics. Where available, studies referring to vocational education have been included as well.

Changing attitudes

The observed differences across the reviewed European countries in the uptake of S&T in higher education can be attributed to a myriad of reasons that are difficult to separate. Some of the highlighted differences are due to so-called cultural or social differences: people in different countries have different attitudes towards S&T. At the same time, there are also fairly consistent trends across all countries, such as a relatively skewed gender distribution, particularly in the more 'hard or technological' sciences such as physics and engineering.

Awareness

These attitudes towards S&T are not necessarily fixed or unchangeable. People form attitudes in part due to lack of knowledge about S&T and develop misconceptions with regard to the general characteristics, specific content and opportunities available within the area. Various awareness campaigns show that once awareness of a particular issue is achieved it can – albeit slowly – change behaviour in significant ways. Thus it is not surprising that, as we have observed, a major effort of governments consists in raising awareness of S&T.

There are various areas in which awareness could be raised, namely awareness of

1. S&T as a field of study (aimed at increasing the supply of potential S&T students, including gender specific measures);
2. the various areas within S&T (aimed at increasing student retention or shifts of non-S&T towards more S&T-related topics);
3. career opportunities for S&T (aimed at specific markets such as engineering, education, research, industry, etc.);
4. labour market dynamics within S&T (either discipline- or gender-related issues);
5. the influence of S&T on society (aimed at general populace).

Why are all five foci of awareness essential? These five foci of awareness cover the spectrum from early acquaintance and general acceptance of the role of science in everyday life, to understanding distinctions between disciplines, and to choice regarding a future in science as well as acceptance of S&T in society. The first four are very much interrelated; the outcome of the fourth is highly dependent on success in each of the earlier foci. The fifth type is essential to establish a common and fertile ground regarding the image of S&T. The cohorts of people that will eventually run through this spectrum will most probably be less ignorant about science. However, this does not imply (or guarantee) that more people will choose science or technology. So where to start?

- Awareness of science as a field of study: the saying 'unknown, unloved' sums up the necessity to increase awareness of S&T, preferably from an early age onwards. An American survey of scientists reveals that 61% of the scientists indicated they became interested in science before the age of eleven, and 74% of scientists believe that science should be given the same priority as reading, writing and arithmetic or maths in

elementary school (Bayer Facts, 2004). Furthermore it is essential to counter the ‘anti-science’ attitude that can result from ignorance.²⁹ Although providing information alone is insufficient to counter misconceptions and fear of science, it is often a first and essential step. Primary and secondary schools can play an important role here by offering sufficient courses/subjects and by providing skilled – and preferably inspiring – teachers. This raises the issue of teacher training, that we will elaborate upon in the section regarding quality.

- Awareness of the variations within S&T: on the tertiary level many sciences are characterized by specialisation. The seemingly solid discipline chemistry will fragment into a number of different types (e.g. organic, an-organic and biochemistry), while some disciplines seem to blend into new and unknown subjects (e.g. biophysics), making it difficult for freshmen students to choose the ‘right’ study. As is indicated in the section on student retention below, wrong study choice is an important cause of drop-out, in particular if it is compounded by insufficient learning skills and study approach (Pitkethly and Prosser, 2001).
- Awareness of possible futures. While job availability is not *the* most important determinant of study choice, it is still important and therefore it may increase enrolment if students are aware of the range of professions that can be pursued after graduation. In addition, it may be that the student is not aware of the science requirements for a particular career or the various routes towards a career.
- Awareness of career opportunities: When employed it may turn out that the job is less satisfying than expected, and may lead to choosing a different profession. The latter can be countered when an alternative can be sought within one’s own discipline and employers can advertise effectively into a smaller market of matching candidates.
- Awareness of the influence of S&T on society and everyday life: This awareness is fed by personal experience and, lacking that, by media attention and to a lesser extent by information campaigns. It is not uncommon that awareness of a particular issue is enhanced when there are high profile advocates or ‘champions’ that draw attention to it, focusing attention of stakeholders and the public and keeping the discussions and developments in the public eye. In Finland, Nokia has obviously taken this role.³⁰ In Italy there is now indeed a growing interaction with local industry, while in Germany the local industry is also beginning to develop closer bonds with education.³¹ The experience in Finland may indicate that government could (or should) invite large players to take a more active and visible role to increase the profile of science. On the other hand, this ‘hero model’ cannot replace the need and the responsibility for government to assist and support additional measures to increase the status and pervasiveness of science, technology and innovation in society.

²⁹ Such as the perceived fear of food additives (fed by stories of detrimental side effects on child behaviour or health) when they are identified by E-numbers instead of their own household name. For instance E330 is citric acid, a normal substance in some fruits – citric and other – and vegetables; only severe overindulgence can result in an upset stomach.

³⁰ Despite the Dutch origin of Phillips (a world leader in innovation), Shell, Unilever, DSM etc., the Netherlands seem to lack such an active champion.

³¹ In addition to institutional players, champions can also be represented by personalities. The recent media attention for André Kuipers and his trip to the International Space Station immediately led to increased attention in all media for space, science and technology in the Netherlands.

Table 7-1

Policy measures aimed at or resulting in increased awareness of S&T by country

Awareness of	field	variation	future	career	society
Finland	LUMA	TiNA	IDBM	TEK recruit	
		MIRROR	IT-related	Assoc of	
		Flexible Study	upgrade	TEK-	
		Right	MIRROR	graduates	MIRROR
Germany					
Ireland	Task Force	Task Force	Task Force		
	Ch&Ph- Intervention IT2000	LCVP	LCVP IT2000		
Italy	SeT				
Sweden	SciTechBaseY	NRC			SciTech
	SciTech (NOT)				(NOT)
	NRC				
U.K.	PSETW	WISE, PSETW	WISE, PSETW	WISE, PSETW	WISE
	SAS	Headstart, SAS	Headstart	SETNET	PSETW
		SETNET	Everything...	ATHENA	
		Everything...	SAS	SAS	
		Specialist			
		Schools Programme,			

Which of the policy measures in our review address these issues?

In Table 7-1, we have tried to include the policy initiatives examined in this study that primarily aim to raise awareness of S&T or have the expected effect of raising awareness in any one of the five ways listed above. The initiatives are organized by country. Because we concentrated on measures in higher education some cells could be underrepresented.

A first glance supports the earlier impression that Finland is very active, with initiatives covering four of the five aspects – the latter one likely missing only because it was not included in the initial search. The UK is also very active, with WISE and PSETW covering all five issues, even if these are mainly aimed at the female population. On the other hand, Table 7-1 also shows that no measures are included from Germany and only one from Italy. While from expert interviews it is known that in Germany and Italy industry does approach students in vocational and higher education, increasing their awareness of their future options and perhaps even career options, these are not government-initiated policies and as such are not included here. Regarding the effect of these close ties: research shows that students at educational institutes (in particular vocational education) that have close ties with business and industry have higher intrinsic motivation and a larger connection to their chosen profession, both of which are closely related to study persistence and career satisfaction (Castellano et al, 2003; more in the section on student retention below).

A balanced and high-quality science teaching at primary and secondary education increases awareness of S&T as a field of possible study. All measures that aim to improve teaching in basic education – by improving skills, dissemination of best practices – are interpreted as adding to this type of awareness, even though it may not be the primary aim of the measure. This is why a number of initiatives of, for instance, LUMA, which are in fact aimed at knowledge sharing between schools, are interpreted as adding to the awareness of S&T as a field of study. The SciTechBasis Year that is in fact a ‘top off’ year creating an extra chance to choose S&T, is also interpreted as such a measure as it also informs the students of the variety of disciplines in higher education.

However, the most comprehensive initiatives, covering all the five aspects, were developed in the UK. These initiatives are specifically aimed at women, and have been in place for many years. The WISE and PSETW initiatives in particular seem to use a ‘shotgun approach’ to the awareness issue, including

- general tools such as media campaigns, brochures, websites and posters;
- more targeted tools (e.g., knowledge sharing infrastructure, courses - some targeted per age group – and presentations); and
- personalized tools (e.g., mentoring, role models).

The more personalized tools may cater to specific gender-related issues elaborated on below in the section on gender, but the other tools may serve to increase awareness within the male (student) population as well. The broad range of issues addressed in these (almost umbrella-like) policy programmes may also turn out to be essential to their success.

Gender

The highly skewed gender distribution in science is a topic of hot debate, often implying that “there is a vast repository of wasted potential that would be utilized if only enlightened policies were enacted” (Webb et al, 2002; High Level Group, 2004). This point of view builds upon the assumptions that the reasons girls and women do not chose S&T are mainly (if not all) external. In this section we will examine the validity of this assumption.

Many reviewed policy measures are aimed at increasing the female participation within S&T. Only one measure (primarily aimed at increasing quality of teaching) anticipated an increase of the male participation.³² Policy measures included in this review that seem to have increased female participation are characterized by

- Initiating a different (often more practically oriented) approach to sciences – increasing the connection to everyday life and people, showing that science is fun to do;
- Creating a ‘second chance’ to choose science-oriented subjects;
- Providing female- and peer-group support, often on a person-to-person level by active mentoring.

Why do these aspects seem to be essential? Girls and women relate differently to science, in particular in a co-educational system. In those countries where there is or has been single-sex education, girls perform as well – and sometimes better – in science-related subject than boys (e.g. Pomerantz & Rydell Altermatt, 2002; Hamilton, 1985). With regard to mathematics and arithmetic at primary level, girls do, in general, perform better. However, around the age that they move into secondary education, boys overtake girls. A number of explanations can be submitted here, many of which have been the object of psychological and educational research:

- **Teacher-to-pupil behaviour:** Teachers behave differently towards boys and girls: Boys are given more time to answer questions, take up between 50% and 75% of the teacher’s time in science classes, are more dominant in the science classroom and perhaps ‘claim’

³² The Teacher Curriculum under the LUMA umbrella aims at improving teaching skills by upgrading the S&T requirements for entry into teacher training. Of course, this may result in fewer women applying, simply because they do not qualify, thus changing the gender ratio. It is not clear if this requirement will indeed lead to an increase in male students.

more attention (Brutsart & Van Houtte, 2002 list many examples). In general, girls receive less feedback, which is anyway of a poorer content and a lower motivational and supportive quality. While such clear variations in teacher behaviour have been recognized, even very subtle (non-verbal) variations in teachers' behaviours and expectations of students' performance seem to influence the learning outcome (Pygmalion Effect). This effect may not be the one-way street it is often assumed to be, and teacher-to-pupil behaviour is, at least in part, a reaction to pupil-to-teacher behaviour (Rosenthal, 2003, Harris, 1998) with women and girls contributing to stereotyping in science education because of gender dynamics elaborated on below.

- **Perception of performance:** Boys and girls interpret their own role in their performance differently: in general girls more often attribute low performance to themselves, underestimating their performance unnecessarily. They feel less in control of their own success. Boys, on the other hand, tend to attribute their success to their own excellence, and confronted with failure look for explanations outside themselves – thus feeling much more in control of their own performance and tending to overestimate their skills and performance (i.e. Dunning et al, 2003). There is a long history related to these perceptions of control (locus of control, Rotter, 1954) and its influence on learning and gender-related issues in science education. Furthermore, even when women perform well in academic and science settings, they feel more uncomfortable about it, perhaps resulting in underperformance (Pomerantz & Rydell Altermatt, 2002). There are indications that girls would need more encouragement, preferably from people (or women) they trust, and more experience of success in learning science, to change their way of thinking, to stop underestimating themselves, and to have a more objective view of their performance.
- **Gender group dynamics:** Stereotyping and gender identification contribute to girls perceiving science as 'unfeminine' (Maccoby, 2002; Harris, 1998) . When boys and girls are in the same classroom there is increased peer pressure to conform to 'being a girl as defined by the group' (e.g. Harris, 1998) and not choosing 'boys' subjects' such as physics and science. In single-sex groups, within group dynamics can help girls to develop a different, perhaps more science-oriented niche. Airnes describes a study on same-sex biology, where girls indicate that their performance improves (Airnes, 2001) because it is 'easier to ask questions', 'you don't get embarrassing comments from boys' and classroom behaviour is also better because in co-ed classrooms '...boys act immature and carry on and distract me'. Peer-group pressure in co-educational settings on girls may become less daunting over time as they mature, which supports the need for 'second chances' over study choice.
- **Gender one-on-one dynamics:** When boys and girls are paired in science classes, girls in girl-boy pairs will very often perform worse than they would in girl-girl pairs (Underwood et al, 1990; Underwood and Underwood, 1997, Dalton, 1990). In mixed pairs or small groups the boys tend to 'take over' without paying much attention to suggestions made by girls. This effect can even be demonstrated in co-ed classes, where pupils work side by side. Girls in mixed-sex classes consistently perform worse than when they have half their classes in single-sex groups (Hoffmann, 2002). Evidence on single-sex science education also indicates that there is no adverse effect on the boys' performance (Airnes, 2001). This may indicate that co-ed science education is actually the worst possible situation for girls as yet unsure about their commitment to science, amplifying stereotyping and performance underestimation.
- **Gender differences:** There seems to be at least anecdotal evidence that girls have a distinctly different way of approaching some subjects: appreciating more contextual

information, in particular if this gives insight into personal histories, social developments and so on. Girls and women seem to approach ‘knowing’ more often in a slightly different light ‘using empathy in an attempt to share the experience behind the idea, ‘feeling with’ and ‘thinking with’ the author of the idea’ (‘connected knowing’, Clinchy, 2002, p. 75) versus the more ‘scientific’ knowing or ‘separate knowing’ where a more separate (objective) stance is preferred and which is more common amongst males (but not purely gender related). This type of approach to knowing incorporates the possibility that there may not only be one ‘right answer’ – an approach mostly at odds with much of the science education at lower levels, which may also partly explain the indications that women/girls perform slightly less well in multiple-choice assessment tasks (Stumpf and Stanley, 1998). For many years the scientific consensus maintained that these differences were social constructs, but more recently there has emerged a growing appreciation of possible evolutionary and biological causes of gender differences (Pinker, 2002). Be that as it may, differences in epistemology may have consequences for the way boys and girls experience teaching and the type of teaching and assessment that is most effective for either sex.

Which of the policy measures in our review address these issues?

The policy descriptions we have analysed do not indicate whether any of the policy initiatives included in this review indeed address directly any of the above listed gender-related issues. It is unclear to what extent knowledge of these issues and effects have been taken into account in designing the policies. In fact the surprise expressed in some evaluations that girls seem to benefit more from some measures supports the assumption that often these dynamics are relatively unknown. On the other hand, the acknowledgement of gender differences is not necessarily broadly accepted and neither is the potential effectiveness of different gender approaches in education.³³

In Table 7-2, we have included the measures that seem to have a gender effect, either by design or otherwise. While the descriptions of the measures do not indicate recognition of the underlying gender dynamics, we have interpreted some measures aimed at improving teaching quality more broadly and have included, for instance, LUMA Network specifically – even though its effectiveness has not been evaluated – because it aims to disseminate knowledge on how to improve science education for girls. While in Finland there are ongoing efforts aimed at women, there also seems to be some recognition that an overall equal representation may be ‘a bridge too far’ (e.g. TiNA, aiming for 33% women) and as such these measures seem to indicate awareness of possibly unavoidable gender differences with regard to study and career choices.

³³ Steven Pinker has eloquently elaborated and argued against the underlying fears of acknowledging individual (and gender) differences in his book “The Blank Slate” (Pinker, 2003).

Table 7-2

Policy measures aimed at girls or effecting girls more strongly by country

Issue	Teacher	Performance Perceptions	Group dyn	Boys2Girls	Different approach
Finland	LUMA Network		Spec.Admission (Tampere) TiNA		Spec.Admission (Tampere) MIRROR
Germany					
Ireland		Task Force			Task Force, LCVP
Italy					Women in Eng.
Sweden		SciTechBasis Year	SciTechBasis Year		
U.K.	PSETW, SETNET	WISE, SETNET PSETW	PSETW		

Examples of measures that benefit girls more than boys are

- The SciTechBasis Year in Sweden, which has contributed to an increase of female enrolment in S&T. It is probable that measures that in fact create a ‘second chance’ inadvertently help girls escape from the **gender group dynamics** or same-sex **peer pressure** that is evident in co-ed settings. In a similar vein, the various special admission routes into higher education address this issue. Examples are the Special Admission at Tampere University, TiNA in Finland, Women in Engineering Professions in Italy, which in fact create a temporary same-sex or female dominated science-education environment. The success of these initiatives cannot be unexpected, as a quick Internet search shows that throughout the world, there are many successful, often small-scale initiatives implementing temporary same-sex education with the aim of increasing science or technological skills of female students. The success of these initiatives lies partly in student retention (see the section on student retention) and in changing the participants’ perception of their own competences and skills. However, because of the scale, the success does not often show up in national or regional statistics.
- The three Irish initiatives are characterised by a **different approach to teaching**: aiming for a more practice-oriented curriculum in primary and secondary education: the Chemistry and Physics Intervention Project, the Taskforce on Physical Science and the Learning Certificate Vocational Programme (LCVP). Girls now outnumber boys at the technical colleges, which is a somewhat unusual circumstance. It is possible that a more practice-oriented curriculum is a first step to more inquiry-based learning and as such gives girls (and also many boys) greater opportunity to access a more ‘connected knowing’. Experiencing (by experimenting) may help the girls (and boys) to understand science, scientific thought and scientific practice better. The reform also included the issue of assessment which may influence the almost structural undervaluation of performance and so lead to greater uptake by girls. It is unclear here to what extent the new curriculum also encourages teachers to change their teaching practices towards a more mastery-oriented focus (in contrast to a content- or performance-oriented goal). Should this be the case, this would amplify the gender effect by countering science avoidance and self-handicapping behaviour based on underestimation of performance in boys as well as girls (see in the section on quality; Turner et al, 2002).

- Campaigns aimed at mentoring, person-to-person interaction such as WISE and PSETW are designed knowing that women often lack a **peer group** (in the sense that there are few fellow females in S&T). While this is true and the activities seem to work well in the UK, where the share of females in S&T has risen steadily over the past decades, by providing personal mentors and successful female role models, they may unknowingly also counter the often prevalent **underestimation of performance** that is typically female.

The need for perseverance and patience

Many issues raised are about changing attitudes to science, scientists and their role in society. But attitudes are notoriously slow to change. There are a number of reasons why changing attitudes and practices in education will require a sustained effort over decades rather than years.

Whose attitudes do we need to change? We need to change the attitudes of different stakeholders, both in the educational system and in society:

- **Teachers'** attitudes towards teaching and the teaching of sciences in particular. Teachers have set ideas about how they need to teach and what type of teaching will illicit the desired type of learning from students. These views are deeply rooted and seem difficult to change (e.g. Trowler and Cooper, 2002; Trigwell and Prosser, 1996) and are often expressed by the teaching-learning regime (TLR) used by the teachers.³⁴ Once teachers have entered the educational system, these views become part of the system, until educational development programmes, designed to improve learning and teaching practices, are developed and implemented, helping the teachers to change. To illustrate the timeframe involved one can draw attention to the period necessary to absorb computer literacy skills into the system.³⁵ This example only reflects the inclusion of a clear skill, not necessarily drawing on the teacher to change their views on teaching or their TLR. The particular problems of this latter change are elaborated further in the section on quality.
- **Pupils' and students'** attitudes towards learning science and becoming a scientist. Learners bring pre-existing ideas to new learning situations, which are often difficult to change. In the context of science education these ideas are often naïve, incomplete and do not show any real understanding of scientific thought or core scientific concepts. An educational approach aimed at developing thinking skills, changing ideas and preconceptions has been shown to have long-term effects in raising achievement (Harlen, 1999), while the process of bringing about change in ideas takes longer than is often allowed for in curriculum planning. The way learners are introduced to science and nurtured into developing 'scientific thinking' emphasizes yet again the importance of quality, and the skills and attitudes of science teachers. It may be that on an individual level, for each child, the change can be fairly rapid, needing perhaps only one or two inspiring teachers or courses in a school career to influence one's choice. However, we will not know what can be achieved by this generation until it has reached its place in society, and that will take at least one or two decades.

³⁴ The term TLR refers to a set of rules, assumptions, practices and relationships related to teaching and learning issues. TLR is introduced by Trowler and Cooper in the context of higher education but one can assume that similar regimes exist in primary and secondary education.

³⁵ It has taken at least two decades since the development and more or less general availability of the PC for it to trickle down to the level of primary schools in developed countries, and even now the computer skills of teachers are only slightly better than those of many their students.

- **Parents** are most probably prone to the same misconceptions with regard to science, gender bias and parent-to-child behaviour patterns as teachers, without the professional responsibility to examine or amend their attitudes and perceptions. While parents perhaps have less influence on the career choice of their children than they would hope, studies show that scientists, particularly female scientists, felt they were supported by their parents in their interest. Almost two-thirds of male scientists and some 74% of female scientists believe it is very important for parents to emphasise science as an important subject to learn (Bayer Facts, 2004). Experiments with new curricula (mostly more practical based) have been successful in increasing parent involvement in science education at primary and secondary level, with good results on learning outcomes (Shymansky et al, 1998, FIPSE III projects, 1996a).
- **Employers** do not pay sufficient attention to the needs and career planning of women. While unemployment under S&T graduates is clearly lower than for other disciplines, statistics show that women working in S&T are more likely to become unemployed (see section on employment in chapter 3). Furthermore it is not clear to what extent women suffer from the so-called 'glass ceiling' (i.e. 'the old boys are not letting us in') or more from the 'sticky floor' ('I don't know if I am able to do this and can I combine this with my other responsibilities?') and habitual underestimation of their performance (see 6.1.2). Employers can play a significant role in breaking through the glass ceiling by making sure women are offered equal opportunities. In addition they can help 'un-stick' the floor by offering women sufficient options to tailor their professional life towards their expectations.
- **Society** as a whole is influenced both by the place of science in history and the current attention it is receiving, e.g. in the media. In countries with a sound industrial base it would seem that S&T is less unusual a career choice than in a country where industry is of economically limited influence. In societies where there are no examples of high-profile technological influence, or influential people promoting science, governments might be required to put more effort into supporting privately and industrially based promotional initiatives.

Which of the policy measures in our review address these issues?

The need to change attitudes is often mentioned as one of the aims of policy. In particular the larger programmes in the UK are outspoken and policymakers have realized that this goal implies sustained effort and a broad range of targets: both WISE (since 1984) and PSETW (since 1994) are still ongoing and cover many of the target populations or stakeholder groups. Again we interpreted measures aimed at knowledge sharing with regard to teaching practices as including the aim of attitudinal change (including LUMA, the Irish measures, SETNET) even when this is not specifically mentioned in the policy (SeT in Italy).

However, changing attitudes of various stakeholder groups is not the only issue discussed here. We also address the need for patience when using awareness campaigns to change attitudes. In previous chapters we have already commented on an important characteristic of the more successful measures, namely their longevity. In Table 7-3 we have indicated these long-lasting initiatives by shading them green, signifying more than 10 years.

Given the non-exhaustive review of policy measures it is possible that other appropriate measures have not been examined in this review. In this regard it is perhaps not surprising that parents are not often mentioned as targets for attitudinal change, neither is society as a whole. Employers are targeted, but often to inform them of opportunities, while policies are aimed at encouraging them to create more workplaces or internships. Only ATHENA specifically addresses raising awareness of the career obstacles and development needs of (female) scientists.

Table 7-3
Policy measures aimed at changing attitudes, by country

Target	Teacher	Pupils/ Students	Parents	Employers	Society
Finland	LUMA Network, LUMA In- service Teacher Training, MIRROR	IT-related upgrade prog., MIRROR TINA		TINA	
Germany					
Ireland	Task Force Ch&Ph Intervention Prog. IT-2000	Task Force Ch&Ph Intervention Prog. IT-2000			
Italy	SeT			Decreto 279- 99	
Sweden	SciTech Basis Yr, SciTech (NOT)	SciTech Basis Yr, SciTech (NOT)	SicTech (NOT)		
U.K.	WISE, SETNET	WISE, PSETW SETNET	WISE	WISE, ATHENA, PSETW, SETNET	WISE, PSETW

Considering the relatively good position of Finland in the S&T discussion, it is remarkable that Finland persists in paying attention to attitudinal change. However, this also shows the awareness at policy level of the need for a sustained effort, perhaps indefinitely. The increasing female uptake in the UK gives reason to evaluate the major effort of WISE, PSETW and other measures as successful. The drop in male participation in S&T in the UK might benefit from a similar effort aimed at specific groups of the male (student) population.

Teaching and learning: improving quality

There is a wide body of literature indicating that particular study approaches lead to a higher quality of scientific understanding and educational attainment (Biggs and Collis, 1982; van Rossum and Schenk, 1984; Prosser and Trigwell, 1999, etc.). Many of these studies draw the conclusion that teaching students to think should be the real focus of education, while much of the current education system seems to focus on transferring large bodies of knowledge (i.e. facts) without actively promoting understanding of the underlying concepts. Science education, particularly at lower levels, is often perceived this way by teachers and students. This perception contradicts the view that science education should foster understanding of scientific approaches and encourage scientific thinking. Many of the researchers contributing to the literature discussed below are former science teachers that have run into this particular teaching paradox. For instance, both Prosser and Trigwell are former university physics professors who discovered that traditionally accepted teaching methods did not give the kind of learning outcome they felt was necessary for the students to become scientists.

Despite the supporting research, little of what is studied and published finds its way into the actual teaching practice. In addition to the restricted exposure to these findings, Branson, among others, implies that “[j]ob responsibilities of teachers provide little discretionary time to plan and think. As a consequence, teachers must ignore significant psychological research (...) on assessment, behaviour analysis, learning and cognitive development” (Branson, 1998).

What affects high-quality learning? Graduates from higher education are expected to be able to think arguments through, to critically assess various points of view, to debate and draw conclusions based on evidence. These types of competencies are often grouped under the acronym HOTS (higher order thinking skills: going beyond the information given, engaging in discovery learning, reasoning, organizing and argumentation; Torff, 2003). What are the aspects within the teaching-learning environment that can influence this result?

- **Teachers' conceptions and practices regarding teaching.** As described before all teachers take preconceptions and ideas on learning and teaching into the classroom, and implement them in their personal teaching-learning regime (TLR). In addition teachers often do not take the time to reflect on their own teaching methods and underlying preconceptions. When these teachers are confronted with curriculum reform based on radically different/new scientific insights, they may not be able to implement the desired change without sufficient training and support. Curriculum reform can then be reduced to using new words and concepts for essentially old teaching methods. Research seems to indicate that this is the case, implying that improving teaching cannot be reduced to "developing teaching skills, or about flexible delivery or about giving students choice. These are all important characteristics of good teaching, but should not be the primary focus of attention" (Prosser and Trigwell, 1999). Kember (2003) concludes: "Staff development initiatives (...) might be a first step in helping them change first their perspectives and then their approaches to teaching. However, perspectives or conceptions of teaching are deeply held and firmly rooted beliefs about practice, and these (...) are not easily challenged and changed."
- **Teaching skills and subject expertise.** It is one of the ironic paradoxes of higher education that staff are expected to be able to teach at a high level based on their expertise in a particular research area. Here in particular, the implicit influence of their personal teaching conceptions can be substantial. At lower levels teachers are educated in teaching methods and skills, but this need not mean they are much better off. The entry requirements for teacher training are often not high for science and thus teachers often feel insecure about their own expertise and skills for teaching science or technology subjects. While the previous point addresses perceptions on teaching and touches on fundamental issues regarding teaching in general, it must be well understood that improving teaching skills and increasing teacher efficacy and self-confidence is necessary. There is a body of evidence suggesting that when teachers feel insecure about their own science skills, they are not only reluctant to engage in teaching these subjects even when they are a compulsory part of the curriculum (Wenner, 2001), but they will also revert to more traditional teaching methods aimed at transferring knowledge resulting in lower quality learning outcomes (specific references given in Wenner, 2001, p. 182).
- **Learners' conceptions** and experiences of learning. Learners of all ages take ideas about learning and good teaching with them into the classroom. These ideas can be split into five or six categories (Säljö, 1979; Van Rossum et al, 1985) and similarities have been established with students' epistemological development (Perry, 1970; Van Rossum et al, 1985; Baxter-Magolda, 2003). Research in the early 1980s already demonstrated the clear relationship between students' views on learning, their understanding of significant educational concepts, study approach and learning outcome. They perceived that deep-level study approaches led to qualitatively better learning outcomes (Van Rossum and Schenk, 1984; Van Rossum et al, 1985; Chan, 2003), in the sense that the outcome is characterized by a deeper understanding of concepts and argumentation. As such, encouraging deep-level study approaches are particularly germane to science education.

Changing learners' views on learning may prove essential to becoming scientists; fostering HOTS, learning to ask the right kind of questions, and accepting that some questions do not as yet have answers (e.g. Fipse III projects 1996c; Torff, 2003).

- The effect of the **educational organisation** on the teaching environment. Teaching aimed at fostering higher order thinking skills (HOTS) requires that the teacher is less controlling. It requires the teacher to assume a more coaching role, travelling together with the student and discovering the intellectual development that the student is experiencing (Fox, 1983). In such an environment the student is responsible for his own learning, and when implemented this type of education not only leads to higher intrinsic motivation and a qualitatively superior learning outcome, it also reduces avoidance behaviour, underachievement and drop-out (e.g. Turner et al, 2002; Castellano et al, 2003; Chan, 2003). However, when an educational organisation puts external pressure on teachers and makes them responsible for 'good student performance', even teachers who prefer less controlling TLRs very often revert to a more controlling attitude, which influences the learning environment (Pelletier et al, 2002). Consequently, educational innovations aimed at improving the quality of the learning environment and learning outcome can only prosper in an organisation that supports this goal. Improving teaching quality is not only the responsibility of the teacher; the organisation must provide sufficient support, for instance, by accepting or sharing responsibility for some of the teacher's many tasks, and so provide them with the opportunity to reflect on and change their teaching if required.³⁶
- The **origin of innovation** – trends and shifts in educational policymaking on teachers and educational organisations. If teachers often lack the time to keep abreast of educational research because of the pressures of their profession, this need not be true for policymakers. However, it is not always easy to ascertain whether and to what extent policymaking is based on scientific evidence. Within many countries educational policy moves relatively quickly from one innovation to another and educational researchers wishing to evaluate innovations can only wade in after implementation. The inevitable time lag means that conclusions of evaluation studies often come too late to influence political decision-making, and schools and teachers are pressured to embrace yet another 'approved' innovation (Borman et al, 2003). As such it may explain the attitude of teachers towards educational research and educational innovation, which has not been proposed from the bottom up. This attitude will most probably be absent from initiatives originating at school or faculty level, increasing the probability of institutional acceptance and success.
- Effect of perceptions of learning and teaching on **the learning experience**. Recent study has indicated strong similarities between teachers' conceptions of teaching and learners' conceptions of learning (Van Rossum and Hamer, 2003). The majority of teachers, in particular at the lower levels of education, adhere to the belief that learning means pupils remember what they have been told about the world by the teacher. These teachers unconsciously assume that learners cannot think without first being told how to accomplish this. Inquiry-based learning and related teaching approaches have been implemented from primary level upwards and have demonstrated this assumption to be false (Kite, 2001; Fipse III projects, 1996c). In addition, there are also indications that

³⁶ Teachers in a teacher-centred organisation are often expected to be able to allocate resources, form learning communities, read the literature, design courses, develop new curricula, deliver courses, conduct assessments, maintain discipline, respond to students' individual needs and problems, do action research, and participate in other school activities (Branson 1998). Many of these activities have their own research communities and body of literature.

formal education can inhibit thinking and reduce the quality of learning and thus the learning outcome (Van Rossum and Hamer, 2003), and that instruction characterized by a low emphasis on HOTS, fostering understanding, intellectual development and personal improvement elicits avoidance and self-handicapping behaviour in science pupils (Turner et al, 2002).

- The effect of the teaching environment on **the learning outcome**. Throughout most of the western world now, teaching-centred schooling is the norm. It revolves around individual teachers or groups of teachers developing plans, and deciding about methods and assessment: an organisational approach aimed at making students learn. However, learning is not an organisational phenomenon, but an individual one and so this way of teaching may have reached its upper limit with regard to the learning outcome (Branson, 1998). Teaching-centred teaching tends to focus on transmitting information or content to the student and there is strong evidence that this type of teaching promotes surface-level study approach in students, leading to a relatively poor understanding of the subject (as defined in the SOLO taxonomy by Biggs and Collis, 1982). To evoke a learning approach more aimed at HOTS, and to understand and develop learners' conceptions of the material, education needs to make the shift to student-centred teaching. Research has shown this type of approach leads to higher quality approaches to learning (Prosser and Trigwell, 1999).

These issues and their relationship with personal epistemology and development are often deemed to be very interesting in a theoretical sense, but the practical implications for educational innovation are often severely underestimated. This is unfortunate, because there is a growing body of evidence that suggests that the views of teachers on teaching and learning may hamper acceptance and correct implementation of educational innovation. Evidence in other areas, such as organisational change, could indicate that incompatibility between teachers' and innovators' views on teaching and learning is central to a lack of satisfactory implementations. Furthermore, incompatibility between teachers' views and those of learners regarding their expectations of teaching and learning inhibits meaningful communication in the classroom, increases dissatisfaction on both sides, and thus impedes high-quality learning.

Which of the policy measures address these issues? In this section we have identified how policy measures address the issues raised above, either explicitly or implicitly. However, there is another issue not included in the list above, but which can have detrimental effects on initiatives to improve teaching quality: the inconstancy of policy. Any large reform aimed at educational innovation needs sustained political and financial support and some protection from changing political winds, as Branson experienced (Branson, 1998). The LUMA programme in Finland may be, if continued, an excellent example of policy that takes this into account. SETNET in the UK is an example of a policy initiative that puts structural change of policy concerning SET on the agenda, and as such touches on the issue of policy constancy.

Teachers' TRLs and the effect on learners' views and learning environment. In this section we have assumed that all measures explicitly aimed at designing and disseminating knowledge of new teaching methods may affect teachers' views on teaching (e.g. LUMA Network, Task Force, LCVP etc). One measure explicitly mentions an issue related to TRLs and creating a different environment: the LCVP specifically mentions aiming for a student-centred approach. While the SAS programme in the UK aims at exposing S&T students to a possible career in teaching, it is implemented by providing more teachers and assistant teachers, whose views on teaching and learning may influence the views of the existing body of teachers. On the other hand, this exposure can just as well influence the students' views on learning. However, without much

deeper research into the details of each measure, it is not immediately clear to what extent specific attention is given to the views of teachers and learners with regard to teaching, learning and related concepts such as understanding, knowing, meaning and so on.

Not surprisingly, many of the more comprehensive policies reviewed address the issue of **teaching skills** and the quality of the teaching environment. In particular, all the measures regarding new (e.g. computer science, IT-2000) or additional science subjects (TaskForce, SciTech) in the compulsory curriculum have an aspect that deals with improving teaching skills.

Table 7-4
Policy measures aimed at improving quality, by country

Target	Teachers' TLRs	Teacher Skills	Learners views	Organisation	Origin innovation	Environment & Outcome
Finland	LUMA Network, TiNA, MIRROR	Polytechnic Ref., LUMA primary school curr., LUMA teacher curr.	TiNA	LUMA	LUMA program	Polytechnic Ref. IDBM
Germany*						
Ireland	Task Force, LCVP	Task Force IT-2000	LCVP, Ch&Ph Intervention	Task Force		
Italy	SeT					
Sweden		SciTech (NOT), NRC				
U.K.	SAS	SAS	SAS	Specialist School Prog.		Specialist Schools Prog.

*Although no measures are included for Germany, the expert interview and qualitative data indicated that there have been initiatives to reform the curriculum which have up to now been unsuccessful.

The issue of a **supportive organisation** is not always mentioned in the policy descriptions, but is at times an issue in the evaluation. An example of a measure that specifies reallocation of priorities at school management level is the Irish Task Force of Physical Science, but there are several others that mention improving cooperation often between schools (LUMA) and both the Polytechnic reform in Finland and the Specialist School Programme in the UK the major effort of curriculum specialisation will certainly have included organisational changes.

The measures specifically addressing the issue of the **origin of innovation** are, for instance, many smaller measures included under the LUMA umbrella programme and are often school or regional reform initiatives. The Common Admission and Special Admission Tampere initiatives were both first developed locally and have now found a certain following on a national level. Furthermore there are several initiatives aimed at knowledge sharing and exchange of best practices (e.g. LUMA, SeT) and thus as dissemination of knowledge and real-life experiences with innovations form the bottom up.

Influencing student retention

There are many factors that influence whether students will 'stay the course' and graduate. Literature in this area makes it clear that the issue of retention – and thus of countering drop-out – is complex and seems at times quite “recalcitrant to intervention by tertiary institutions” (Watson, 2004). Research seems to indicate that experiences in the first and second year are important determinants for student withdrawal or drop-out (Pitkethly and Prosser, 2001; Scott et

al, 1998). The various factors influencing student retention can be categorized into groups that may be influenced by policy – directly or indirectly – and those that may not. Given the fact that retention of students in S&T is generally lower than in non-S&T studies, influencing these factors could assist in lowering drop-out rates for S&T students. Issues that can be directly influenced by government or institutional policy are:

- **Climate** on campus: the attitude of staff and students, competitiveness versus collegiality, social versus performance-aimed, the atmosphere of the learning community and so on.
- **Choice:** knowledge about courses available, poor course choice, choosing the wrong field of study.
- **Skills:** insufficient learning skills; insufficient life skills.
- **Financial issues:** access to grants, fellowships, stipends, hardship funds and the like.
- **Learning environment** and its effect on important indicators for student retention: intrinsic motivation, and personal development; and views regarding the relationship between learning and life; meeting students' expectations.

Why are these issues important? Central in study retention (and attainment) is the issue of meeting the students' expectations. This does not mean that institutes of higher education and policy should aim at conforming to the sometimes passive and 'schoolish' expectations of freshmen students. The difficult task of institutes of higher education is often the opposite: how to encourage students to develop their way of thinking and their approach to learning. To achieve this, institutes and perhaps educational policies should include a developmental perspective and consider how to encourage change at a pace that prevents unacceptable drop-out levels.

- **Climate:** For many freshmen students the move from secondary to higher education involves a major change in life. Managing this large change is affected by the climate at the educational institute. When it is experienced as unsupportive or inhospitable, making it difficult for students to find their way, and students fail to find a support group, this makes the adjustment even more difficult and puts a strain on study motivation. While this issue is relevant to all students, it may be particularly relevant to science courses as these know lower enrolment and relatively high drop-out. The Rollins College in the US has experimented with providing science and mathematics students with a 'Science Community Year' (SCY) designed to create a 'learning community' of students following similar science and maths courses, helping students to cope with a the demanding curriculum. The community includes a 'master learner': a faculty member who is himself a novice in the subject area and takes the courses along with the students. In the first semester, the SCY already resulted in higher science enrolment by SCY-students (71% against 56% for non-SCY students) and a high completion rate (68% against 53% for non-SCY students). The SCY increased science and maths enrolment after two semesters by 65%, an increase from 31% to 51%. Women and men benefited to a similar degree, indicating that improving the climate will contribute to student retention, but not influence the gender distribution very much (FIPSE III projects, 1996b), a result also found in other studies (i.e. Strenta et al, 1994). Other examples where schools have formed 'learning communities' or 'schools within schools' – e.g. Career Academies and Career Magnets – have shown similar results. These initiatives, which started as early as the 1970s as drop-out prevention measures, have been transformed into fully fledged school reforms because of additional effects on student performance and teacher job satisfaction (Castellano et al, 2003).

- **Choice:** Relating to the subject or profession chosen is an important indicator for success (Watson, et al, 2004). A realistic view of what the subject or profession entails, leads to realistic expectations, and negative study experiences may affect personal motivation less severely. On the other hand, when a subject turns out to be too difficult, drop-out is imminent (Strenta et al, 1994; Baillie, 2000; Pitkethly and Prosser, 2001). Information supporting subject and course choice, if applicable, combined with tailored study advice and mentoring, will help students understand what studying is about and help them to make better choices. In some cases this will mean that they leave S&T, in others it could mean they change their subject.
- **Skills:** A number of initiatives in the US (i.e. the FIPSE Projects III, 1996b) show that programmes particularly at junior college level, but also at primary level, can influence the way students perceive science and mathematics and their own competencies. Projects at college and undergraduate level, which develop problem-solving skills in combination with self-management skills, such as time and budget planning, self-discipline and so on, seem to be especially effective in increasing student retention throughout science education (i.e. FIPSE III projects, 1996a en 1996b). Early attrition in science is very often caused by low grades in first- and second-year courses (i.e. Baillie, 2000), which in science are very often correlated with gender. This underscores the need for programmes such as Women in Engineering Professions, TiNA, MIRROR and the Science BasisTech Year treated above.
- **Learning experience:** Study retention in later years, as well as successful re-enrolment, is largely explained by student motivation (i.e. Allen, 1999; Scott et al, 1998; Baillie, 2000) and there is no difference between ethnic groups or men and women in this regard. Motivation is negatively influenced by unresponsive, non-motivating teachers and inferior instruction (Strenta et al, 1994). In previous sections the relationship between teaching quality, learning outcome and (de)motivation has been discussed extensively. In summary, teaching and instruction that is less controlling, mastery-centred instead of performance-centred, aims at developing HOTS, (e.g. learning to ask the right kind of questions and accepting that not all question have only one answer), is essential to science and the development of high quality domestic science communities.
- **Finances:** The influence of financial considerations on study choice is not at all straightforward. While there is no empirically supported evidence that within higher education direct costs, such as tuition fees, influence the choice between disciplines (Frinking et al, 2003), there has always been concern regarding access to higher education for less affluent groups within society. Access to information on available financial support, how to apply and so on, as well as information on financial repercussions if no grant or scholarship is available, are several avenues by which policymakers can approach this issue.

Which of the policy measures in our review address these issues?

Although the issue of attrition is recognised from secondary school upwards to professional or career attrition, it is noteworthy that in this review four of the six countries have not developed many measures nor have they tried to address the wide range of issues specifically connected to attrition. In addition there are measures that address peculiarly national problems (categorised in 'other') such as the long study duration in Finland due to employment of non-graduates, such as the Graduate! Initiative.

Again, the UK initiatives WISE and PSETW address multiple issues, and although these measures are aimed at women, many of the issues addressed are equally valid for the male student population. These initiatives deserve close scrutiny to determine which aspects can be transferred

to counter the drop in male enrolment. There are also two UK initiatives that address changing or influencing S&T policy (PSETW and SETNET) and as such may – in the long run – have an effect on student drop-out as well as career attrition.

Climate: IDBM aims at increasing cooperation between faculties/disciplines and involving industry by creating multi-disciplinary projects. Both of these aspects could increase motivation and satisfaction and so counter drop-out. WISE, PSETW and ATHENA aim at improving the general atmosphere for women in S&T. In particular, PSETW includes influencing labour conditions (and so indirectly campus climate for the staff) as well as attitudinal change in students. SETNET aims at attracting motivated and high-quality people to S&T, which under normal circumstances should improve the working and social environment.

Table 7-5
Policy measures aimed at lowering drop-out

	Climate	Choice	Skills	Financial	Environment /quality	Other
Finland	IDBM		Spec. Admission TiNA		LUMA, MIRROR	Graduates School Syst. Graduate!
Germany				Bildungs- kredit		
Ireland						
Italy			Women in Eng			
Sweden			SciTechBasis Year			
U.K.	WISE, PSETW ATHENA SETNET	Headstart WISE, PSETW Everything you wanted...	WISE	Everything you wanted... , Investing Human Cap.	Specialist Schools SETNET	PSETW SETNET

Choice: Initiatives specifically aimed at helping prospective S&T students to make the right choice are Headstart, a summer school for students already interested in S&T, and the general information service ‘Everything you wanted to know’, which provides information on courses, financial support options, career opportunities and the like. WISE and PSETW, as expected, address many issues regarding attracting women to S&T including information on study options, career choices and so on.

Skills: Here again we included those initiatives specifically aimed at improving science skills, e.g. TiNA, Women in Eng. Professions, etc (see Table 7-5). In this review we have not included measures aimed at improving life (not learning) skills, such as budgeting, study discipline, organisational skills etc. Freshmen students can experience severe difficulties during the first years of their studies if they are not able to organise their life to accommodate learning. There are experiments that prove that students who acquire these skills early have a much better chance of graduating on time or at all.

Financial: In this section we included only measures aimed at financial support of students. ‘Everything you wanted to know’ does not in itself provide support, but it provides access to information about various types of financial support. The Bildungskredit is a general student financing measure. Students in Germany rely heavily on their parents for support and if this is difficult they often resort to working. Dropping out because of money shortage is not uncommon and the Bildungskredit aims to prevent this type of drop-out (Frinking et al, 2003). Investing

Human Capital offers financial support to post-graduate students by providing funds for post-graduate research places.

Environment/quality: In the previous sections we have illustrated the effect of teaching quality on the study outcome. In the section on gender, we discussed the issue of problem-oriented teaching and its effect on girls' performance in science settings. In the section on quality, the issue of views on learning and teaching, their effect on the learning environment and learning outcome was discussed extensively. The effect of the learning environment on students' expectations, study satisfaction and motivation has been researched less. However, combining the research on teachers' expectations (expressed in teacher-pupil behaviour), teachers' views on learning, teaching and their TLRs, and the effect on the way they organise their teaching and assessment, gives sufficient grounds to make some assumption of transitivity of effects. The effect of fundamentally different approaches to teaching on the learning experience and learning outcome have been studied extensively (e.g. van Rossum and Schenk, 1984; Trigwell and Prosser, 1996; Baxter Magolda, 2003; Kember, 2003; van Rossum et al, 2003), and links have been made to motivation and study persistence (e.g. Strenta, 1994; Allen, 1999; Baillie and Fitzgerald, 2000; Borman et al, 2003). The demotivating effect of teaching that does not live up to student expectations is a well known issue, but much less publicised, because many believe it is difficult to influence through policy. However, van Rossum gives distressingly clear descriptions of this student disenchantment in his report of 2001. In this publication, students describe how low-quality teaching and low-quality assessment can force them to adopt more reproductive learning styles than they prefer, resulting in lower quality learning outcomes (van Rossum et al, 2001). This implies that improving teaching quality will influence motivation and, as such, the major driver to counter student attrition. In this sense, all the measures included in section on quality, should be listed in Table 7-5. However, here we have chosen to include only those measures that explicitly include countering drop-out as one of the aims.

Labour market

In all but one of the seven countries reviewed, there is serious concern about the sustainability of the current level of supply of S&T capacities. Only Finland does not anticipate serious labour shortages. The main moments when S&T students and graduates leak away to other disciplines and careers, resulting in labour shortages in S&T professions are:

1. insufficient numbers of S&T graduates flowing out of HE to satisfy immediate and future needs;
2. S&T graduates choosing a non-S&T profession or career;
3. S&T professionals leaving an S&T career;
4. difficulties in attracting and retaining foreign scientists to alleviate immediate shortages.

The measures included in our review cover all these possible causes, one country focusing more on one issue than another.

How to influence the drivers that underlie these four 'causes'? About half of the countries in this review have had a large and prosperous industrial base (Germany, Italy, and Finland more recently). In these countries, technology often has a relatively good image and is seen as a reasonable career choice. Often the vocational branch of S&T education is well developed and has its own market for graduates. In Germany and Finland, industry is involved throughout higher education, introducing the options and attracting potential graduates to S&T studies. However, the European policy goal to become the world's leading competitive and dynamic knowledge economy is placing pressure on all countries to increase their national research and

innovation base. While industry and educational institutes need to shoulder the larger burden regarding developing and implementing initiatives to reduce the outflow of potential S&T students and professionals, the focus of this study is on government policy development and how it can support these efforts. In this section we will therefore be looking at the four avenues of ‘loss’ – can we establish how serious they really are and in what ways policy can make a difference?

- **Insufficient outflow from HE:** This issue is addressed by a large number of policy measures described in the previous sections of this report. The question here is whether there is evidence that non-S&T graduates can flow into more S&T-type professions. An American study following some 1,100 high-potential students interested in S&T, aged between 13 and 33, shows that a substantial majority of 60% chose a math-science study and proceeded into a math-science career. Although indeed a sizable number of the participants chose a non-math-science study, this need not mean that they are ‘lost to S&T’ forever. Indeed at age 33, some 17% of these non-math-science graduates were employed in a math-science profession, such as mathematics, computer science and medicine (Webb et al, 2002). This demonstrates that it should be possible to attract and retrain non-math-science graduates to provide an additional source of S&T professionals.
- **Outflow of graduates to non-S&T careers** is a serious concern. After all the effort already invested in improving S&T education at all levels, increasing enrolment and reducing drop-out, it is unfortunate to lose potential S&T scientists at the very last moment. The share of S&T graduates, who do not pursue an S&T career, differs from country to country. A major reason to choose a different career path is a change in interest and as such this is very similar to study choice (see section on yield in chapter 3 as well as Webb et al, 2002). The responses of students leaving S&T indicate that a change of interest in a subject may also be part of wider processes and “imply more a journey of personal self-discovery” (Webb et al, 2002). It is difficult to imagine policy options that can influence such a change of heart, but there are other courses of action available. Job availability and potential earnings are important reasons to choose a career in S&T (refer to the section on yield in chapter 3) and both these issues are amenable to policy influence.
- **Outflow of S&T professionals towards other careers:** When there is a shortage of S&T professionals, retaining as many professionals as possible in the sector seems the most efficient path. Even at this stage, a certain percentage of professionals may experience a personal ‘change of heart’ and, as stated above, it would seem difficult, if not undesirable, to try and influence this through policy. On the other hand, while unemployment for S&T graduates and professionals is low on average, there are some worrying exceptions: female S&T professionals and the mismatch between skills and labour market needs.

Women have a far greater chance of becoming or remaining unemployed (see the section on yield in chapter 5). The issue of female presence in the S&T professional community is recognized, and needs to be addressed across the board. Policies aimed at retaining females would need to be based on insight into the mechanisms that (1) disadvantage female graduates with little work experience, impeding them from pursuing a budding career and (2) mechanisms and obstacles that result in women losing heart, giving up and turning away from work environments that do not meet their needs or preferences (see the section on gender in this chapter and the discussion on the ‘glass ceiling’ versus ‘sticky floor’ before). Many of these mechanisms are subtle and may not be clearly understood or recognized by the employers. Policy and research aimed at these

mechanisms would be a good start, followed by clear standards, regulations, or incentives to ameliorate existing practices that disadvantage women.

The mismatch between skills or work experience and industrial needs is illustrated in Germany where large groups of technical and scientific professionals are unable to find employment (see section on yield in chapter 5). Policies regarding life long learning (LLL) and initiatives regarding upgrading existing experience are options through which policymakers can address loss of expertise and perhaps even long-term unemployment for certain groups of scientists and engineers.

A third issue germane to losing S&T professionals is the lack of career development opportunities for graduates and post-graduate S&T students. In the review, there are a number of initiatives regarding the immediate future of graduates and post-graduates, such as those that create research places in the public and private sector, as well as initiatives regarding LLL.

- **Outflow of S&T professionals towards other countries (brain drain).** Brain drain is an issue that has been on the political agenda for many years now. There is the issue of Europe losing scientists to other countries (more than 15,500 graduates and post-graduates moved to the US between 1991 and 2000). Over 75% of these scientists do not plan to return to Europe immediately, and are considering a long-term stay in the US (Ned. Tijdschrift Geneeskunde, 2003). The main reasons for this are the excellent research climate, the flexible career development opportunities, and the high standard of living. The many opportunities to work in excellent science communities is draining Europe of its best graduates, which is especially unfortunate since the years immediately following a PhD are often very scientifically productive. Given the reasons indicated for the brain drain, European governments should consider establishing similar centres of excellence throughout Europe and provide these with sufficient funds and facilities to attract and retain top-quality scientists. There are also opportunities to initiate policy measures aimed at providing more post-graduate research jobs at existing institutes and encouraging private investment in R&D.
- **Difficulties in attracting high-level foreign S&T professionals** to meet the national or near-regional supply. Brain import is often seen as a temporary solution. National and European regulations regarding immigration are an obstacle for brain import. It is relatively easy to amend regulations, but the cost of implementing new procedures and preventing overuse of brain import can be considerable, while the effectiveness and sustainability of the measure are hard to assess. In addition, this type of measure does not address the structural issue of insufficient domestic supply.

Governments feel the need to be able to control immigration, and while they are willing to be more lenient for highly trained professionals, they often limit the effect of brain import by issuing work permits for specific time periods or developing permits for specific types of professionals (or even for certain nationalities). Time-limit permits undermine the structural nature of this kind of solution: scientists will need to return to their own countries or move elsewhere. Unlimited permits may have other disruptive effects on the labour market. It is an option policymakers approach with due consideration and which requires careful evaluation.

Which of the policy measures address these issues? Insufficient outflow of S&T students is, to a certain extent, the result of an inadequate number of students choosing S&T, and the measures addressing this have been discussed previously. However, the review includes a number of measures explicitly designed to affect one or more of the issues raised in the list above.

Table 7-6
Policy measures aimed at labour market issues

	Career choice	Job availability in HE	Work environment	Industry	Immigration
Finland	TEK- Ass. of Eng, IT-related intake IT-related industry intake, IT-related upgrade, IT-related temporary upgrade, TEK-recruitment, IDMB	IT-related Grad. Pos., Graduate School System,	LUMA Network	TEK recruitment IDMB prog.	
Germany		Junior Professor			Green Card
Ireland		Post-Grad. Stipends	Post-Grad. Stipends Task Force	LCVP (prac. places)	Work Visa
Italy	Decreto 279-99		SeT	Decreto 279-99	Re-entry Scientists
Sweden					
U.K.	SAS WISE, PSETW	Investing Human Capital ATHENA	ATHENA PSETW		Highly Skilled Migrant Prog.

In Table 7-6 we have summarized which measures address each particular route.

Influencing career choice toward S&T: Finland has developed quite a number of contingency plans, mostly IT related, in anticipation of future shortages. These initiatives include improved information access on career opportunities (TEK recruitment, Ass. Of Graduate Eng), increasing the number of study places (IT-related intake, Graduate School System) as well as initiatives aimed at attracting non- or near-S&T students and graduates to S&T careers (IDBM, IT-related temporary upgrade etc.).

Improving job availability (in HE) would require a sufficient increase in budget to provide for additional (temporary) post-graduate and post-doctoral research positions. Of course these positions may require additional funds for expenses and facilities to fulfil their potential. In the long run, policies aimed at improving job availability will need to address issues of continuity that touch on career development and working conditions. Examples of initiatives focusing on the short term are the German Junior Professorships and the Finish Graduate School System, which creates graduate and post-graduate positions for a limited number of years. Initiatives that have the longer term in mind are the UK initiative Investing Human Capital and the Irish Post-Graduate Stipends which both include post-doctoral positions.

Improving working conditions can be interpreted as improving facilities or salaries, or as improving working conditions, including career development, life planning, return options and so on. For S&T disciplines in particular, the investment in facilities and equipment can be essential and substantial. An example of the former type of initiative is the Post-Graduate Stipends measure implemented in Ireland, where graduates receive additional student financing through earmarked funds and the average earnings of post-graduates are increased by more than €20,000 per year to establish competitive salaries. In the framework of the LUMA Network, some €1.7 million is invested in improving facilities and equipment. There are more initiatives that focus on investment in facilities such as SeT, the Task Force on Physical Science, and IT-2000. The ATHENA and PSETW policies address improvement in working conditions in particular in light of gender differences. ATHENA even includes financial incentives for employers to improve the environment and to create a more female-friendly organisation. Given the high attrition rate for women in S&T this approach warrants consideration.

Providing incentives for industry The number of measures included in this review aimed at providing industry with incentives to create S&T-oriented positions is not large. Again this may be the result of the initial selection, aimed at higher education. The Irish vocational reform includes incentives to create more practice places where pupils can learn in a 'real-life' environment. The Finish IDBM initiative is somewhat similar, encouraging companies to provide practice places and projects for students of higher education. Decreto 279-99 in Italy provides scholarships to increase mobility towards industry, as well as tax exemptions to encourage industry to create research positions. The TEK recruitment is a bit of an outlier here, as it is aimed at providing graduates and industry with a targeted market for job mobility.

Import of professionals: Four countries have designed policies or simplified procedures to attract scientists from outside. The UK and Ireland chose to simplify procedures to increase immigration of highly skilled professionals. Italy and Germany developed new initiatives. While Italy is trying to limit this immigration to nationals by giving tax breaks to returning Italian scientists, Germany's problem is its limited access to a clearly defined range of skills. None of these measures has officially been evaluated. While the available data on the German Green Card seems to indicate that there has been a considerable inflow of (mainly Indian) IT-specialists, other sources indicate that the majority of Green Card holders are foreign students who have completed their studies in Germany and are now looking for work, resulting in a relatively high unemployment rate amongst Green Card holding IT-specialists, and additional costs to the state in unemployment benefits. The Irish Work Permit has also led to an influx of professionals, but the permit is much less specific and covers a number of non-S&T professions as well. In sum, the available information on importing expertise does not give much insight into its effectiveness with regard to S&T.

Synthesis and conclusions

The general overview of the state of S&T in higher education shows that the observed countries have quite different levels of performance. It must be stated that these countries have been confronted with quite different challenges. Thus, the urgency of S&T-related problems is not necessarily found at the same stages or in the same manner from country to country.

Overall, we can distinguish three groups:

- Finland and Sweden are currently primarily dealing with employment issues and those related to the later stages of tertiary education (post-doctoral researchers and working conditions).
- Germany and Italy have consistent problems at the early stages of higher education (especially enrolment), which make them weak performers almost across the board. Given the unfavourable demographic developments (negative growth rates, low proportion of 0-19 years olds) this situation will not seem to resolve itself.
- Ireland and the UK have experienced considerable relative drops in S&T studies, especially with respect to the enrolment of male students in higher education. Furthermore, the supply of skilled teachers is also considered an important issue here.

These different perspectives regarding the most urgent issues to address have resulted in many different policy measures, each with its own aim and purpose. The policy measures and structural developments experienced in these countries can be considered from at least three different perspectives, which we address in this chapter:

- Direct focus on the people that can be targeted
- Focus on the disciplines within S&T itself
- Attention to systemic elements that could impact S&T uptake.

The final part of this chapter lists a number of recommendations regarding effective policy measures and approaches.

Attractiveness of S&T in relation to specific target groups

Female students have been the most important specific target group considered in these countries, followed to a much lesser extent by students from low-income families.

Gender differences

Uptake of S&T in higher education has always suffered from a gender gap. In all of the countries surveyed female students are disproportionately underrepresented in S&T subjects. This is

already an issue in secondary education but is partly disguised by mandatory uptake of subjects such as mathematics during this stage in education.

In 2000, the share of women in the S&T student population was highest in Italy and Sweden, while Finland, Germany, and Sweden had similar proportions compared to each other (approximately 30%). In our sample of countries, the Netherlands suffered from the biggest gap between men and women in uptake of S&T in higher education.

Although all countries examined in detail have seen growth in the share of students in the past 20 years, they have experienced quite different developments during that time period (see also figure 3-8). Germany, the UK and Sweden have witnessed considerable increases in the share of female participation, while Finland and Italy have remained constant at relatively high levels, and the Netherlands at low levels.

Interestingly enough, the under representation of women seems to be exacerbated by the fact that women in S&T are more likely to become unemployed than men. This issue has specifically been recognized and addressed by a number of UK policy initiatives such as ATHENA and WISE, which have been evaluated as successful. Their results have been expressed in growing numbers of female students in S&T studies relative to men.

Often these differences are attributed to socio-cultural and traditional factors rather than elements in the structure or contents of education; boys are often more encouraged (by teachers, parents, society at large) to choose S&T than girls. The problem consists of a number of phenomena. Low self-confidence, underestimation of performance,³⁷ and discouraging teachers are partial explanations. Girls are often more interested in and, intentionally or unintentionally, are directed to social sciences and languages. This is partly underscored by differences in choice behaviour for the various disciplines (see also below), but similar choice patterns in each of the countries surveyed.

However, some of the evaluation reports (e.g., LUMA evaluation) have asserted that teaching quality, methods and attitude at primary and secondary education, and changes therein, have a significant impact on the attractiveness of S&T that seems especially to affect girls. The current teaching material and methods in S&T are considered to be better suited for boys. The introduction of a Junior Leaving Certificate in Ireland is believed to have been an important boost for the uptake of S&T-related subjects by girls as it provided new impetus and additional attention for these subjects by using specially qualified teachers.

Looking at the statistics, Finland has not significantly been able to affect the gender imbalance in higher education S&T, despite a number of long-term policy measures that were aimed directly at attracting more female students. At the same time, it has been capable of maintaining the same (relatively high) proportions of female students in an increasing S&T-student population. In this respect, policy measures such as Mirror and TiNA are not considered failures, but necessary parts of more comprehensive approaches.

Finally, the SciTech programme (Sweden), which was designed to provide second chance opportunities for entrance to secondary education, was successful in general, but unintentionally more so for women. Although not supported by empirical evidence, this could lead to the observation that the overall secondary school environment does not provide enough support and incentive for girls who are hesitating to choose S&T. In a less preconditioned environment, this group could still take that second chance offered by a transition or preparatory period.

³⁷ Current Directions in Psychology, 2003.

Other groups

Relatively little is known about whether the participation of deprived socio-economic groups or ethnic minorities is a specific problem for S&T. There is also little theoretical or practical evidence that there are structural components that could hinder the uptake of S&T subjects by these groups. Obviously, tuition fees or insufficient financial backing could block the opportunities for students who are from lower income families. Here there is evidence that students with a working-class background are underrepresented, but not specifically in science subjects.

Finns believe that free higher education is a particular strength of the system. Germany has increased provision of financial support mechanisms, which are believed to have benefited science students slightly more than other students. However, hard evidence is not available to prove that this mechanism has been a determining factor in the choice behaviour of German students.

Otherwise, there are no policy measures designed to improve the attractiveness of S&T for other minority groups in the student population.

Stimulating the attractiveness of specific disciplines

There is clear evidence in all of the countries surveyed of a growing lack of interest in taking up S&T subjects in higher education, particularly the classical subjects such as mathematics, physics, and chemistry. This is somewhat compensated for by an increase or stabilisation of numbers in more modern science subjects such as biotechnology and computer sciences.

We observed that there is a clear difference in the performance of countries across the various S&T disciplines. If we distinguish the natural sciences from engineering and technology, it becomes clear that the overall high position of Finland is driven by good performance of engineering and technology subjects, while Ireland benefits from a high proportion of students in natural sciences.

Similar to the biased gender choice, one could argue that in Finland and Ireland much of this choice behaviour is influenced by traditional and cultural factors.³⁸ However, in Ireland the growth rates for mathematics and natural sciences have surpassed the overall student population growth rate over the last ten years, while similar developments appear to have occurred for engineering and technology in Finland. In short, if traditional preferences exist, they have even been reinforced in the past ten years.

Changes in the structure of education or the curriculum might have supported these developments. In Ireland, we already mentioned the Junior Science Certificates at the end of lower secondary education, which were deemed successful because they provided increased attention to science as a separate subject while using dedicated and qualified teachers. In Finland, many different initiatives could be linked to the overall increase in S&T, but the upgrading of the polytechnic within the structure of higher education might have contributed to significant growth rates, particularly in engineering.³⁹ In the raw statistics, it is clear that the slightly declining share of S&T in the student population in higher education was turned around. At the same time, the share of female S&T students has experienced similar increases. Unfortunately,

³⁸ This pattern is also reflected in the industrial organisation of countries such as Germany, Sweden, and Finland which have much greater relative expenditure in the machinery and equipment sector compared to, for example, the UK and the Netherlands, which have their prime investments in chemicals, rubber, plastics, and fuel.

³⁹ The post-secondary vocational training was re-organised in the early 1990s and polytechnics were created. The aim was to channel the increase in higher education provision to polytechnics rather than universities, and at the same time diversify higher education. This resulted in a substantial increase in polytechnic students as was planned. At the same time, in the technology sector, the vocational education of technicians ended.

our statistical data for Finland does not provide insight into the share of women in natural sciences and in engineering subjects to support any interrelationship between the specific disciplines and gender choice.

Stimulating attractiveness at various stages of the supply chain

Our conceptual framework focused on the range of factors that could influence the inflow and outflow of S&T pupils, students, and researchers at various stages of the supply chain. In each chapter, we looked at status, structure and policies for each of them. The actual inflow and outflow, the structural aspects of education systems and labour markets influencing this, and the policy measures that are aimed to prevent outflow, are not necessarily linked in a straightforward manner. The following paragraphs aim to highlight areas where policy activity has taken place and to link these with S&T status and structure.

Mandatory education and quality of science teaching

Given the mandatory nature of education in primary and lower secondary education, there are obviously no differences in uptake or drop-out for S&T. At the same time, there seems to be clear differences across the countries examined in the way that schools have to provide attention to science-related subjects and the intensity with which this occurs. The effect of these differences on the volume of S&T students in higher education is hard to measure.

However, it is clear that policymakers increasingly recognise the importance of building specific science curricula to draw attention to the potential of S&T subjects at the early stages of education. At primary education levels this is expressed in explicit or non-explicit attention to S&T, where the balance increasingly favours the explicit attention.

This increased attention goes hand in hand with improving the quality of teachers. The Junior Science Certificate, mentioned above, the Irish Task Force on Physical Sciences proper, and the LUMA programme in Finland each explicitly addressed these issues.

In the UK, all levels of science teaching suffer from a lack of qualified teachers, which is due in part to relatively unattractive earnings. Teacher training is therefore a priority and the national network of science-learning centres is being developed to support teachers in acquiring the necessary expertise and skills. It is worth noting that the Wellcome Trust, a private charity, manages this network.

Connection between choice in secondary education and access to tertiary education

The actual uptake of S&T subjects in secondary education is a result of how specific a choice a high school pupil can or has to make. For Italian pupils, that choice does not really exist, so figures on the level of uptake are not available. In other countries, such as Germany, pupils are required to select a number of subjects from various disciplines (i.e., science and non-science) which also means we cannot measure the number of people who drop S&T altogether.

For the UK, Sweden and Ireland, we have some indications about the uptake of specific S&T subjects. In the UK, the numbers of pupils who choose a science A-level reflects very well on the proportion of science students in higher education. This could indicate a high correlation between the choice-moment at age 16 and the actual choice behaviour for tertiary education. This straightforward relationship is not surprising as entry into higher education is determined on the performance in A-level subjects. Similar mechanisms exist in Ireland and Germany.

Some of these countries have recognized the fact that an early choice in combination with performance in secondary education as an entry determinant for tertiary education does not provide flexibility for those students that regret their choice. Both Germany and Ireland provide

alternative routes through vocational education to S&T studies. However, such alternative routes are not used very intensively.

Sweden and Ireland have recently focused on incorporating transition years so students can better prepare for a potential specialisation in S&T, by creating more realistic expectations of S&T studies, with the aim of establishing a lower drop-out rate. While the attractiveness of S&T has increased and stabilized, we have not been able to determine decreased drop-out rates for these countries.

In general, we can distinguish two different structural approaches: on the one hand, some countries such as Ireland and the UK provide early dedicated choices for S&T in higher secondary education that provide a path into S&T in tertiary education. The philosophy here seems to be that an early choice could prevent drop-out later on. On the other hand, there are countries that provide fairly balanced curricula in secondary education (with different degrees of emphasis on S&T) but with no formal connection to entry in tertiary education. In addition, in this latter group of countries there seem to be more possibilities for transition, or preparatory years, in case pupils decide to change the overall direction of their subjects' orientation.

Prevention of drop-out in tertiary education

We have stated in previous chapters that, in general, the drop-out rate of S&T is higher than in other fields of study. Even in Finland, where the ratio of graduates to entrants for non-S&T subjects steadily declined to the point where the assumed drop-out rate was close to zero, the drop-out rate of S&T remains fairly high at between 20 and 25 percent.

We were not able to address the contents or quality of S&T studies and its potential effect on drop-out across countries in a reliable manner. However, we did observe a number of policy measures that were oriented towards preventing drop-out of students (although not necessarily attracting *more* S&T students) and aimed at providing a more interdisciplinary environment, with opportunities to combine non-S&T and S&T studies or possibilities to enter and exit from studies originally chosen. Again, Finland has a number of measures designed to accomplish this (IT upgrade, Graduate!). Germany has focused on providing more interdisciplinary studies, and the UK in providing additional stipends for post-graduate students. Others focused at preventing drop-out from S&T because of:

- Incorrect perception of the study (UK)
- Lack of skills (UK, Italy, Finland, and Sweden)
- Lack of time due to professional engagements (Finland)

In addition there are a plethora of measures aimed at decreasing drop-out, but not specifically aimed at S&T, e.g., in Germany, which are not included here.

Most of these initiatives have underachieved: the anticipated positive impact was not accomplished in the least. Providing more ways to combine courses have almost been counterproductive in the sense that S&T students seem to make use of these initiatives more so than the other way around; additional stipends in the UK have not been significant enough to seriously address the issue.

Direct involvement of industry

Low enrolments, high drop-out, and a move away from S&T-related careers, even by S&T graduates, are often the result of people's perception that public or private research and science do not provide attractive careers.

There have been many policy measures (often set up in cooperation with entrepreneurial sectors) aimed at this countering this perception. Germany introduced Junior Professorships to provide

better prospects for career development in academic research. High-profile involvement of industry, aimed at fostering interest in a career in industry and research, such as is practised in Finland, would seem to counter perceptions of unattractiveness. On the other hand, a more low-level approach of regular exchanges between S&T students or graduates and industrial sites in place in Germany is also said to have had a positive effect on perceptions. Other measures which have seemed to be successful are:

- Development of demand-driven courses (Finland, IT upgrades etc.)
- Industry-sponsored internships, professorships, research posts or post-doctoral fellowships (i.e. Finland, Italy).

Establishing comprehensive policy approaches

The real impact of individual policy measures seems to be difficult to assess. In many countries arguments are put forward that stimulate broad packages of policy measures aimed at various stages of the educational cycle.

We selected a relatively large number of initiatives from Finland. This was because of both the consistency of attention they paid to S&T issues in education and the labour market, and their interesting nature. While we observed that most of the key issues related to status were about the labour market, the breadth of issues addressed and instruments used in Finland went well beyond that narrow focus. There are indeed important linkages between industry and students, but the stimulation of S&T has included the intake of students in higher education, female participation, the quality of the teachers, and the flexibility of the studies.

None of the measures evaluated in Sweden were directly aimed at the labour market. In fact, most measures were aimed at stimulating enrolment in S&T studies by increasing interest and building transition years to provide students with a better idea of S&T's potential and scope. Some of the measures were introduced a number of years ago and thus were focused on the past situation. Looking at the longer-term developments, the focus on stimulating entry is self-evident and could even be considered very successful: growth rate in S&T has been higher than other fields of study, leading to a gradually increased share of student numbers (from below 20% in the 1990s to close to 30% in recent years). Similar increases regarding female students can also be observed.

The Roberts' review in the UK very systematically identified a number of issues specific to higher education that reduce the attractiveness of undergraduate education in mathematics, engineering and the physical sciences. The review also recommended a wide range of new policies based on its analysis. Given the current state of flux in the policy debate in the UK, it is not yet clear which of these policies will be implemented and which will not. Those types of measures not considered by Roberts and introduced as far back as the 1980s have been focused on female enrolment and matching supply and demand in the labour market. The latter focus is also addressed in recent initiatives, making use of more financially oriented mechanisms. Similar to the Finnish method, therefore, the UK has taken a very broad approach, addressing weaker aspects of S&T in higher education and beyond.

Finally, the activities that were headed by the Task Force on the Physical Sciences were also established to address a broad range of issues to reverse the declining numbers of students opting to study the physical sciences in Irish schools and colleges.

Recommendations

The complexity of the issue and the underlying causal dynamics require a comprehensive approach

Given the important impact of culture and tradition on choice behaviour, evaluation reports and feedback from stakeholders have stressed that formulating broad ranges of policy measures is required to make an impact on the uptake of S&T in higher education on the overall volume of the supply of S&T researchers. Stakeholders in the various countries have indicated that the focus of policymakers should not be on individual measures. Countries that are currently perceived by others as successful have either implemented their comprehensive programmes more than two decades ago and/or already started with relatively high levels of S&T students and researchers. In addition, the comprehensiveness of the suite of measures would include a focus on S&T education on all levels (LUMA, Task Force etc.). On the other hand, to increase the local impact, it may prove necessary to tailor measures specifically to local or institutional needs (LUMA). This latter characteristic supports the conclusion that policymakers should not focus on one individual type of measure.

This type of change requires a long-term perspective and long-term commitment of resources

Changing the beliefs and perceptions of individuals is a difficult job. All the evidence indicates that when these beliefs are not made explicit, and are made an object of reflection, beliefs and perceptions are particularly resistant to change. This means that policymakers should not only be more aware of these beliefs and perceptions, and make greater effort to think about ways of changing them, but that measures should also be designed to be in place for significant period of time. Structural change in the overall share of S&T students in higher education should only be anticipated in the long run.

To identify effective policies it is necessary to emphasise the need for evaluations based on measuring effectiveness

The concept of 'evidence-based' policy has only emerged in the last few years, and is accompanied by a growth in the demand for performance measurement and policy audits. In the past, accountability was interpreted in a more budgetary or financial way, leading to a tradition of more procedural evaluations, if policy was evaluated at all. This study has also shown that the effectiveness of individual policy measures is difficult to measure. Few evaluation reports have been able to demonstrate explicitly the impact of specific policy measures. In part, this is due to a lack of evaluation criteria formulated at implementation. A compounding factor here is that for many policies effects are foreseen for the long run, and in this period many external factors interfere. These arguments only emphasise the need for a structured evaluation plan and regular monitoring.

The scarcity of data on the effectiveness of policies is a serious obstacle to policy analysis and policymakers should include provisions and requirements to facilitate such evaluations in the future.

Gender balance in all S&T disciplines cannot be anything but a long-term objective, and it may prove to be extremely resistant to change

Women are often perceived to be a largely untapped resource as S&T workers, only requiring sufficient 'indoctrination' to unlock the considerable supply. It remains to be seen if this is a realistic view. There is sufficient evidence that women can and do perform as well as men in S&T, and often do particularly well in a non-co-educational system (i.e. Harris, 1998), but many

– perhaps the majority (Pinker, 2002) – might simply be more interested in other subjects. The persistence of traditional choice behaviour (due to gender differences?) would perhaps indicate that aiming for equal representation in each and every one of the S&T disciplines may prove to be unattainable – at least in the intermediate and perhaps even in the long term, especially for disciplines such as engineering. Parity or even female dominance might be possible for other subjects (i.e. chemistry in Ireland).

All in all, many of the measures included in this study seem to have helped address gender differences, and some have led to increases in female uptake. Major discrepancies in certain science subjects still exist, which are mostly related to traditional differences in choice behaviour.

Alternative routes and flexibility of curriculum can help prevent an early lock-out of potential S&T students

There seems to be a difference of opinion in whether choices for S&T should be fixed early in education, that is, in the transition between lower and upper secondary education, or later on, just before or in tertiary education. It would seem that introducing transition or preparatory years between secondary and tertiary education (potentially followed by entrance exams) has been instrumental in changing or focusing choice behaviour toward S&T subjects. Also, the possibility of entrance to S&T studies in tertiary education through vocational education seems to have positively affected the entrance of additional numbers of S&T students. However, the overall volume of these alternative routes is relatively small in general. Therefore the overall impact on S&T ratios might be marginal, but still noteworthy as far as boosting these ratios in the desired direction is concerned.

The quality of teachers and the status of teaching should be improved, specifically in secondary education

Improving the quality of teachers specifically in S&T-related subjects has been a widely embraced policy that has had assorted effects on the attractiveness of S&T, especially in secondary education. The key point here is that without sufficiently qualified teachers, who are capable of demonstrating the value of S&T studies, students will lack the sufficient incentive to take them up.

In showing the attractiveness of S&T, the engagement of industry is essential

We have seen many different ways in which industry (or otherwise privately initiated S&T) can be instrumental in developing more attractive career opportunities and perspectives of work in S&T than is currently offered. These ways can be grouped in various approaches:

- Involve industry in promotion to highlight attractive career opportunities
- Involve industry in determining what longer-term skills might be required
- Involve industry in offering work experience programmes to provide hands-on knowledge of S&T-related professions.

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APPENDICES

Appendix A: Specific groups in the student population

The student population in the various countries surveyed has changed during the last decades.

- Perhaps the main development has been the gender shift: female participation in higher education has increased in every country to the point where women have achieved equal representation or are represented in the majority.
- Another development is the increase in the number of so-called ‘mature/adult students’, often facilitated by policy measures.
- And although the data are scanty, the rise of certain ethnic groups in higher education is worth highlighting. This appendix provides additional detail and analysis about these developments.

Women

In all countries secondary education is compulsory until about the age of 16. Consequently, the gender distribution of pupils will generally reflect that of the population. Nevertheless, there are clear differences in the uptake of S&T by gender. There are undoubtedly differences in distribution across other specific groups, based on ethnic and socio-economic characteristics. Unfortunately, only few data exist on the specific fields of study in secondary education. Therefore, we present data below, where available, on a case-by-case basis.

Swedish data (presented in Table A-1) show that S&T accounts for a remarkably high percentage of male pupils (c. 47%) as against a far more modest percentage of female pupils (c. 17%). Women appear to almost completely ignore the technology subjects (c. 2% of students), but their interest in the natural sciences is far more pronounced (c. 40%).

Similar information for the United Kingdom show that science and technology account for just under 30% of all GCE A and GCE AS-level exams. Sciences (biological sciences, chemistry, physics, mathematics, and other science) make up the greater part of these exam results; technology (computer studies, ICT, and design and technology) accounts for a mere 6 percent.

Table A-1
Characteristics of students in S&T in secondary education in Sweden, 1996/7-
1999/2000 (%)

	Share of fields of study in the total student population (%)			Women's share in students by field of study (%)
	men	women	total	
construction	4.4	0.1	2.2	1.8
electrical engineering	8.8	0.1	4.4	1.1
energy	1.5	0.0	0.8	2.5
vehicle engineering	6.6	0.1	3.3	2.0
natural science	26.0	17.0	21.4	40.2
S&T	47.3	17.3	32.1	38.3
non-S&T	52.7	82.7	67.9	61.7
TOTAL	100	100	100	50.7

Source: *Statistisk Årsbog*.

Women are responsible for a significant percentage of exam results in biology, chemistry and mathematics, while their share is much lower in physics and computer studies. On the whole, women account for over 40% of exam results in S&T as against 59% in all other fields of study. When they are compared with Sweden (table 3-3), the British data suggest that S&T attracts more pupils in secondary education (32% in Sweden; 41-42% in the UK) and that the participation of women is somewhat higher in the UK.

In Ireland the most popular S&T subjects in secondary education are mathematics (presumably a compulsory subject), geography, biology, and computer studies. (Table) These subjects not only attract more pupils than the other subjects, but are also the only ones where girls account for a significant part of the number of pupils. Physics and the technical subjects appear to be

TableA-2
Number of examination results for GCE A and AS-levels in the United Kingdom, 2002/2003

	GCE A Levels				GCE AS			
	M	F	TOTAL	%F	M	F	TOTAL	%F
biological sciences	17,724	28,049	45,773	61%	22,743	35,064	57,807	61%
chemistry	15,729	16,590	32,319	51%	19,524	19,837	39,361	50%
physics	20,984	6,144	27,128	23%	23,725	7,575	31,300	24%
other science	2,901	1,283	4,184	31%	5,373	2,507	7,880	32%
mathematics	32,511	18,927	51,438	37%	37,327	24,715	62,042	40%
Computer studies	7,490	974	8,464	12%	10,502	1,456	11,958	12%
ICT	10,977	5,688	16,665	34%	16,817	9,830	26,647	37%
design and technology	9,567	5,875	15,442	38%	11,857	7,267	19,124	38%
TOTAL S&T	117,883	83,530	201,413	41%	147,868	108,251	256,119	42%
GRAND TOTAL	316,989	369,483	686,472	54%	419,666	493,471	913,137	54%
TOTAL NON-S&T	199,106	285,953	485,059	59%	271,798	385,220	657,018	59%
<i>share science</i>	<i>28%</i>	<i>19%</i>	<i>23%</i>	<i>44%</i>	<i>26%</i>	<i>18%</i>	<i>22%</i>	<i>45%</i>
<i>share technology</i>	<i>9%</i>	<i>3%</i>	<i>6%</i>	<i>31%</i>	<i>9%</i>	<i>4%</i>	<i>6%</i>	<i>32%</i>
<i>share of S&T in total</i>	<i>37%</i>	<i>23%</i>	<i>29%</i>		<i>35%</i>	<i>22%</i>	<i>28%</i>	
<i>share women S&T</i>				<i>41%</i>				<i>42%</i>

Source: *National Statistics, GCE/VCE/A/AS examination results for young people in England, 2002/2003*

interesting only for boys, while the remaining subjects (e.g. applied maths) attract only the occasional pupil or are only offered sporadically.

Table A-3
The percentage of boys and girls that studies
S&T subjects in second level schools in Ireland,
2001 (%)

	boys	girls
mathematics	100	100
biology	30	57
geography	56	48
computer studies	29	34
chemistry	12	12
physics	25	8
agricultural science	9	2
technical drawing	24	2
construction studies	33	2
applied mathematics	3	1
physics and chemistry	3	1
engineering	20	1
agricultural economics	0	0

Source: *Statistical Yearbook of Ireland 2003*, p. 109.

Women are gaining on men in higher education. In Germany female participation is approaching 40% and in the UK and Ireland women now outnumber men. The shift is almost always more pronounced in the non-S&T disciplines, such as social sciences, law, and health. Yet even in S&T women are gaining ground.

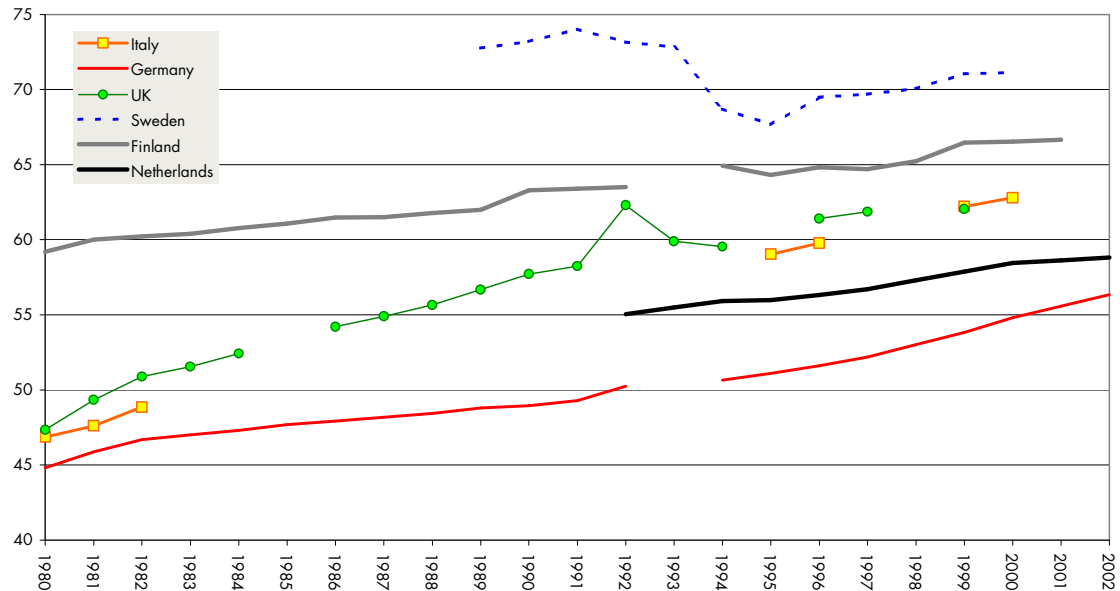
Even in Finland, where most initiatives aimed at increasing female participation in S&T are relatively successful, the increase is larger in non-S&T areas. In Ireland female students now outnumber men at the Institutes of Technology, which now account for about 40% of higher education.⁴⁰ In the UK the gender shift is more pronounced in S&T, particularly in chemistry but also in engineering (where the share of women doubled), computer science and bioscience (Greenfield, 2002). In Sweden women are well represented throughout higher education. There is only one discipline – engineering – where the dominant gender (male) comprises more than 60%. In Italy, where the gender shift is not a priority, women have made some gains in engineering but this is almost masked by the general increase in enrolment. Germany is characterized by a marked S&T decline (in engineering) while the general trend is a rise of female participation of about 2-4% each year (in social sciences languages, economics, law, arts and medicine).

⁴⁰ <http://www.oecd.org/dataoecd/41/40/2675784.pdf>

Figure A-1 and Figure A-2 compare the development of the share of women in S&T and non-S&T subjects since 1980. Virtually every series shows an increase in female participation. The two figures lead to three observations:

Figure A-1

The share of women in the student population in all other fields of study, 1980–2002 (%)



RAND MG270

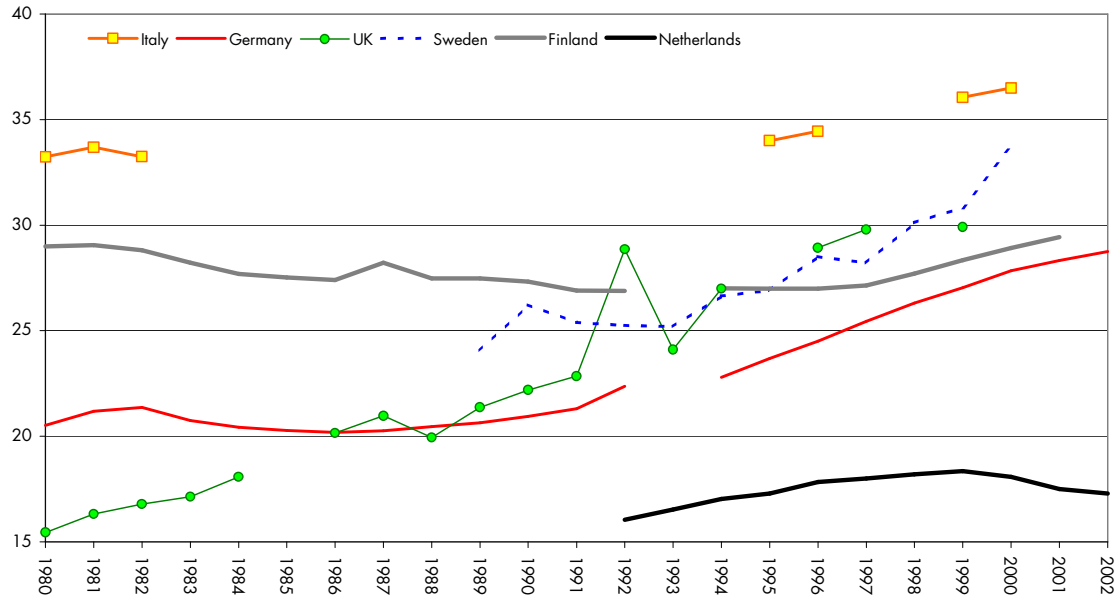
- The share of women is considerably lower in S&T than in the other fields of study. This can be attributed mainly to engineering and technology, where women usually account for only a few percentage points.
- Finland (in S&T) and Sweden (in non-S&T) are two exceptions in that the share of women remained more or less constant. On the other hand, women already had a substantial share in the number of students at the start of the period. The emancipated stance of the Scandinavian countries is evident in the development of the share in non-S&T students. In S&T itself this stance is less obvious.
- The Netherlands and – to a lesser extent – Germany are among the worst performers in terms of gender. In the 1990s Dutch women contributed at least 10% less to the total student population in S&T than in the other countries. In all other subjects only Germany performed worse than the Netherlands, which is still 5 to 10% below the other countries.

Specific age groups

In many countries higher education increasingly attracts so-called 'mature students'. In Sweden this is due to a change in admission regulations (in 1970) to facilitate enrolment for people over

Figure A-2

The share of women in the student population in science and technology, 1980–2002 (%)



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25 years old with work experience. The aim is to increase the level of participation in each cohort to 50% (Salerno, 2002). In the UK the proportion of 'mature' students enrolled in tertiary education is also increasing, although still only about 6% of the cohort is enrolled in higher education.⁴¹ Since unification, Germany has experienced a steady rise of the average age of students until about 1997. The average age of first degree students now stands at 24.7 years. Students from the "new" *Länder* are on average almost 2 years younger than the students in former West Germany (23.4 as against 25.0).

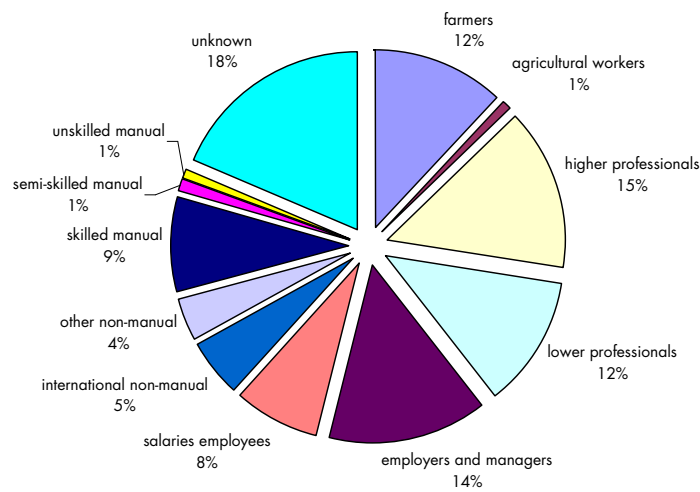
In Ireland the trend is almost opposite. The average age of students is 18.6 years (the OECD average is 20.5 years). This is due to the increase in the number of pupils entering higher education immediately after secondary school (65% in Ireland as opposed to 50% in the OECD). The few 'mature students' mostly study part-time. In Finland the average age of freshmen students is also falling due to policy. The aim is to enrol 66% of all new age cohorts in a university or polytechnics education.

⁴¹ <http://nces.ed.gov/surveys/international/IntlIndicators/pdf/24higheredenroll.pdf>. Alternative vocational routes and courses into higher education are likely to become increasingly important if the Government is to meet its target of 50 per cent participation in higher education (Roberts' Review (2002): http://www.hmtreasury.gov.uk/Documents/Enterprise_and_Productivity/Research_and_Enterprise/ent_res_roberts.cfm).

Social-economic background

In Sweden the proportion of students with working class background has increased by about 25% (from 1 in 5 to 1 in 4), but they are still underrepresented ([Swedish] Annual Report, 2003). In the UK minority groups (when taken together) are well represented, with the exception of Muslim women and black Caribbean men. In Germany student numbers from lower and middle class income groups have been dropping over the last decade. In Ireland the socio-economic gap seems to be closing, with Dublin, the eastern (more rural) and the border counties showing higher levels of enrolment than in the past.⁴² Figure shows that Irish students come from all segments of society: all groups are represented, regardless of their social or economic status.

Figure A-3
Socio-economic background of full-time students in Ireland, 2000/01



Source: Higher Education Authority (www.hea.ie)

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⁴² <http://www.blackwell-synergy.com/links/doi/10.1111/1468-2273.00028/abs/>

Appendix B: Summary of policy measures

	measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
Fi	Common admission for MSc in technol. And archit.	1974 - now	<ul style="list-style-type: none"> – increase efficiency in placement of applicants in study programmes – simplify application procedure – attract good applicants 	national university level initiative and universities are responsible for the implementation (like in all student intake)	<ul style="list-style-type: none"> – facilitative: information access/ exchange non interactive – regulatory: common entry requirements and entrance examinations – costs: approx €75/applicant 	<ul style="list-style-type: none"> – 4100 students, tertiary level – architecture & building – 7 organisations (initially 5) 	<ul style="list-style-type: none"> – using common entry requirements makes possible to enter different entrance programmes without too much trouble and facilitates easy allocation by universities – increase immediate inflow into HE and thus more students 	<ul style="list-style-type: none"> – completed in 2002 – 67% of applicants enter immediately after SE (on average this is 31%) – average age of applicants is 1 yr younger – costs for separate admission systems is calculated to be more – programme underway to standardise entry procedures for all universities
	TEK recruitment	1986 - now	<ul style="list-style-type: none"> – increase efficiency of the labour market 		<ul style="list-style-type: none"> – facilitative: information access on career options and career mobility by knowledge infrastructure – service financed by TEK, cost unknown 	<ul style="list-style-type: none"> – 6000 workers within the S&T focus 	<ul style="list-style-type: none"> – free of charge service for both job seeking members and employers creates an efficient market place for S&T professional. This helps the graduating students to enter the job market and professionals to change jobs later in their career. 	<ul style="list-style-type: none"> – not evaluated, currently about 1,000 jobseekers registered
	Special admission to Tampere Univ of Techn.	1988 - now	<ul style="list-style-type: none"> – increase (female) enrolment in S&T in architecture and building 	local	<ul style="list-style-type: none"> – regulatory: creating alternative learning or access routes – admission tests about €145 /applicant and costs of additional mathematics and physics courses are covered by university. 	<ul style="list-style-type: none"> – Tampere University of Technology – 50 – 130 students per yr (tertiary) with insufficient mathematics levels at SE – architecture and building 	<ul style="list-style-type: none"> – admitting students with normally insufficient mathematics preparation, may increase the number of female students and facilitate shifts towards S&T – time frame: a school generation 	<ul style="list-style-type: none"> – non available – at first the special admission route was female dominated, this has changed – admission is on psychological tests and interviews and seems to select highly motivated students with good communication skills – conflicting info on drop out rate and duration, but seems no worse than average – numbers have gone down per yr from 130 to about 50/yr – other universities have some form of special admission as well

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measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
Polytechnic reform	1990 - now	<ul style="list-style-type: none"> - structural change - increase enrolment overall - improve the quality of education to meet changing needs of industry 	national	<ul style="list-style-type: none"> - regulatory: curriculum reform and increase of teacher requirements - regulatory: restructuring 215 post-secondary vocational institutes into 29 polytechnics - financial: creating study places - facilitative: improving teacher training; increase cooperation - €690 million in total, €5,144 per student in 2000 to approx €6,300 in 2004 (all public, 43% by local authorities) 	<ul style="list-style-type: none"> - 2000 students, 29 institutes and all economic sectors - secondary and tertiary education - teachers 	<ul style="list-style-type: none"> - time frame: a school generation 	<ul style="list-style-type: none"> - 2003 - OECD expert group assessment - improved quality and better match between education and needs
Developing education for electric, electronic industry and ICT (umbrella – see separate IT related measures below)	1994 – 2002 (various programmes)	<ul style="list-style-type: none"> - increase enrolment universities and polytechnics (SET) - engineering MSc upgrading programmes - increase graduate school positions - encourage applicants both in general and female 	national				

measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
Graduate School System	1995 - now	<ul style="list-style-type: none"> - increase S&T graduates pursuing career in education - increase quality of researcher training - shorten time spent on doctoral studies, lower graduation age - increase cooperation (nationally and internationally) 	national	<ul style="list-style-type: none"> - financial: student support and - financial creating study places in fundamental and applied research (providing salaries) - earmarked research funds and financing pilot projects - between €25-32 million/yr for 1500 full-time students - facilities provided by universities - additional 2500 research postings financed otherwise 	<ul style="list-style-type: none"> - 114 research/ educational institutes of which 58 have S&T areas - students by age 	<ul style="list-style-type: none"> - increasing student support and creating reasonably paid research places increases full-time studying and research. This results in better quality graduates that are available for teaching and research time frame 1-5 yrs 	<ul style="list-style-type: none"> - in 2000 survey under school management and students - graduates are now younger - number doubled in 10 years
IDBM (internat, Design Business Management) Progr.	1995 - now	<ul style="list-style-type: none"> - increase awareness - increase cooperation between disciplines/ facilitate multi-disciplinarity - counter mismatch between skills and needs 	Regional University initiative	<ul style="list-style-type: none"> - facilitative: curriculum reform by joint teaching of economics, arts and technology subjects - creating study places, practice places (in industry) - 10 companies participate with a project: each project costs about €10,000 	<ul style="list-style-type: none"> - 30-45 students per year (tertiary) - 3 universities in Helsinki area - design, technology and marketing 	<ul style="list-style-type: none"> - the design business leans heavily on technological and marketing knowledge and vice versa, industry can benefit from design knowledge – information exchange can strengthen the business - time frame 1 – 5 yrs 	<ul style="list-style-type: none"> - no formal evaluation available - there are more graduates with a minor in a design or technology subject - there is an interdisciplinary network between industry, universities and students

measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
LUMA (umbrella policy – covers most of measures below) - information on separate measures is available	1996-2002	<ul style="list-style-type: none"> – increase enrolment overall – increase enrolment SET – increase choice SET career (awareness of options) – attitudinal change 	national	<ul style="list-style-type: none"> – facilitative: Encourage networking (knowledge exchange) between education and other stakeholders – facilitative: Improving teacher training – regulatory: Curriculum reform and improving assessment – financial: Educational access (study places and distance learning) – financial: Improving facilities – €34 million from government, additional funds from educational organisations and €1.4 million from Nokia and €2 million from the Economic Information Office (industry). 	<ul style="list-style-type: none"> – all students and educational organisations – primary, secondary and tertiary – students and teachers 	<ul style="list-style-type: none"> – by increasing and improving the level of teachers, the SET education will improve, the uptake will improve and the yield will improve – time frame between 1 yr and school generation (12 yr) 	<ul style="list-style-type: none"> – in 2002 – self and international evaluation – intake of SET has increased, supported by the increase in polytechnic institutes since 1990 – number of students taking maths and physics examination in secondary school has increased, but not reached target – international comparison of science literacy: Finland is in best quartile – gender inequality has decreased for maths and natural science and disappeared for many other disciplines – this has not lead to different behaviour in senior cycle or tertiary education – skills of vocational students are not up to par yet; Adult science skills are above average – target for teacher training have not been met, but are approaching targets
LUMA - Intake	1992 - 2002	<ul style="list-style-type: none"> – increase enrolment in general – increase number of graduates to meet demand from industry and education 	national	<ul style="list-style-type: none"> – financial: creating study places – €14,3 million in total, with an additional €3 million for teacher training 	<ul style="list-style-type: none"> – students of tertiary education (life sciences, math, physical sciences, engineering + teacher training) 	<ul style="list-style-type: none"> – more study places will attract more students which will result in more S&T graduates overall – teacher training on various levels (class, degree and upgrading programmes) will increase the number of applicants for this career – time frame: a school generation 	<ul style="list-style-type: none"> – no official evaluation – enrolment has increased, but less teacher due to upgrading programmes than expected – higher enrolment is paired with lower initial S&T skills, so this is a problem

measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
LUMA - Network	1992 - 2002	<ul style="list-style-type: none"> - improve quality of S&T teaching in school (i.p. for girls) - increase communication between schools, municipalities and industry regarding skills - disseminate the results of the LUMA programme 	national and local	<ul style="list-style-type: none"> - facilitative: knowledge dissemination between municipalities, schools and other Ed. Institutes + curriculum reform, - financial: investment in buildings and equipment: €1.7 million- See also other LUMA measures 	<ul style="list-style-type: none"> - teachers of primary and secondary education (270 organisations) 	<ul style="list-style-type: none"> - the networked schools will innovate teaching practices - increased communication between industry and education will lead to inclusion of skills that better match demand - time frame: 1-5 yrs 	<ul style="list-style-type: none"> - surveys and interviews in networked schools: - best results when management and municipality were supportive - more successful in schools with more than 1 active teacher - teaching practices have improved; no improvement on learning results, but the climate in S&T is better - occasionally more elective S&T courses available - follow up after LUMA
LUMA – primary school curriculum	2002 and ongoing	<ul style="list-style-type: none"> - increase S&T skills in general and at primary level 	national	<ul style="list-style-type: none"> - regulatory: structural change of curriculum more chemistry, physics, biology and maths from yr 5 upwards 	<ul style="list-style-type: none"> - primary schoolchildren and primary teachers (yr 5 upwards) - life, physical sciences and math 	<ul style="list-style-type: none"> - increased skills in all of society and better results in tertiary S&T education - time frame: school generation 	<ul style="list-style-type: none"> - in 2002 - in LUMA networked schools these subjects have been integrated in subjects such as environmental education, craft and home economics - curriculum content needs to be modernised
LUMA teacher curriculum	1996 - 2002	<ul style="list-style-type: none"> - increase teachers S&T skills in education - more S&T entry requirements 	national and institutional	<ul style="list-style-type: none"> - regulatory: change entry requirements - facilitative: curriculum reform 	<ul style="list-style-type: none"> - tertiary level: students of teacher training 	<ul style="list-style-type: none"> - S&T in entry requirements for teacher training will increase <ul style="list-style-type: none"> o applications of students with more S&T skills o increase proportion of males o lead to better S&T skills in teachers and thus o lead to better S&T teaching and higher uptake - timeframe : school generation 	<ul style="list-style-type: none"> - in 2002; expert evaluation through visits and interviews - quantitative goals have been met, but much to be done to increase cooperation between educational dept. of universities.

measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
LUMA – In-service teacher training	1996 - 2002	<ul style="list-style-type: none"> – improve S&T teaching by improving teacher skills (i.p. math) – disseminate LUMA results and LUMA teaching methods 	national	<ul style="list-style-type: none"> – financial: teacher training – 15-20 extra credits required, each credit is approx. 40 hours study; specific topic courses also available for 3-5 points each – €9.4 million 	<ul style="list-style-type: none"> – 11000 teachers of primary and secondary level 	<ul style="list-style-type: none"> – in service training opportunity will <ul style="list-style-type: none"> ○ increase the S&T skills of teachers lacking such skills ○ improve S&T skills of teachers that already have these skills – time frame: 1-5 yrs 	<ul style="list-style-type: none"> – in 2001 and 2002: international evaluation with survey and interviews – results depend on organisational support and participation by more than one teacher per school – participating in courses during year is difficult – many courses were beneficial, but trainers need more knowledge of daily practice in schools – courses should include more LUMA good practices
IT related Graduate school positions	1998 - 2002	<ul style="list-style-type: none"> – increase S&T graduates to meet need in education and research – increase enrolment of doctoral studies 	national	<ul style="list-style-type: none"> – financial: ear marked funds for research grants, financing pilot projects – creating graduate research positions with focus on applied and fundamental research – €131 million in total (public funding) 	<ul style="list-style-type: none"> – 60 workers in IT, post graduates of mathematics, computing and engineering 	<ul style="list-style-type: none"> – increase in post graduate places will lead to more doctorates and expands pool of professionals for education and research (public and industry) – time frame 1-5 yrs 	<ul style="list-style-type: none"> – no formal evaluation – more doctoral students
IT related industry intake	1998 - 2002	<ul style="list-style-type: none"> – increase enrolment in general – increase number of graduates to meet need of industry 	national	<ul style="list-style-type: none"> – financial: creating study places – increased university intake (+1000/yr) and polytechnic students (+1400/yr) – €74 million/yr 	<ul style="list-style-type: none"> – 2400 students, tertiary level – computing and engineering 	<ul style="list-style-type: none"> – by increasing intake more graduates will flow out of HE to meet industries needs – time frame 1-5 yrs 	<ul style="list-style-type: none"> – in 2000 – a self evaluation and on site visits by an international expert group and document review – number of graduates has not increase proportional to the intake

measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
IT related temporary upgrade programme	1998 - 2002	<ul style="list-style-type: none"> - increase education of graduates from near fields - encourage shift towards IT 	national	<ul style="list-style-type: none"> - financial: creating temporary upgrade programmes and study places in computing en engineering - €131 million overall 	<ul style="list-style-type: none"> - 5150 tertiary students - universities and polytechnics 	<ul style="list-style-type: none"> - professional upgrade programmes for students and workers in near by fields will increase the number of IT related graduates - time frame 1-5 yrs 	<ul style="list-style-type: none"> - in 2001 - surveys and interviews - programmes have started, but progress slower and deliver less graduates than expected due to working students and decreased relevancy of previous field
TiNA	2001-2003	<ul style="list-style-type: none"> - increase female participation in SET education to 33% 	University (Helsinki University of Technology)	<ul style="list-style-type: none"> - training - mentoring - events for women - development of teaching methods - Funded by the European Social Fund EQUAL community initiative 	<ul style="list-style-type: none"> - female students - potential female students - female graduates - teachers (secondary and tertiary) 	<ul style="list-style-type: none"> - information on the career possibilities will attract more female students - the culture at the university will change - networking and mentoring will support S&T career 	<ul style="list-style-type: none"> -
MIRROR	2002-2005	<ul style="list-style-type: none"> - increase female participation in technology, IT by improved teaching methods and material, and by better information, marketing and events 	national (industry association initiative)	<ul style="list-style-type: none"> - regulatory: curriculum reform - facilitative: marketing and events - facilitative: international cooperation - for more details see http://www.mirror4u.net/english/ - funded by the European Social Fund EQUAL community initiative 	<ul style="list-style-type: none"> - female students - potential female students - teachers 	<ul style="list-style-type: none"> - 	<ul style="list-style-type: none"> -
Association of Graduate Eng (TEK)		<ul style="list-style-type: none"> - increase awareness of engineering as career 		<ul style="list-style-type: none"> - facilitative: information access by competitions and events 	<ul style="list-style-type: none"> - secondary school students 	<ul style="list-style-type: none"> - 	<ul style="list-style-type: none"> -

	measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
	GRADUATE!		<ul style="list-style-type: none"> to lower drop out rate in general and in engineering in particular by encouraging students with prolonged study durations to finish 	national	<ul style="list-style-type: none"> facilitative: information access – non-interactive (websites etc) and personal (mentoring) counselling is part of university budget, no specific funds reserved 	<ul style="list-style-type: none"> engineering students who take longer to finish 	<ul style="list-style-type: none"> time frame 1-5 yrs information, networking and study counselling for students who have completed most of their studies but the have been unable to finish them. Typical reason for this is a full-time job. Graduating can help the students in their career and decrease the risk of unemployment 	<ul style="list-style-type: none"> not evaluated
	Flexible Study Right	1998 (some universities in the Helsinki area already form mid 1990's)	<ul style="list-style-type: none"> facilitate combinations of courses over universities 	Helsinki area, from 2004 national – Ministry actively involved in the negotiations	<ul style="list-style-type: none"> access to studies (minor subjects and courses) in other universities 	<ul style="list-style-type: none"> students 	<ul style="list-style-type: none"> no specific effects expected in S&T area 	<ul style="list-style-type: none">
	measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
It	SeT	1999	<ul style="list-style-type: none"> improve quality of science education improve cooperation between schools and institutes for education increase awareness attitudinal change 	national initiative regional	<ul style="list-style-type: none"> regulatory: Curriculum reform facilitative: Improve didactic skills facilitative: Improve network/ cooperation between institutes (horizontal and vertical) financial: Improving facilities funds per project: between €2,065 and €7,230 for each project 	<ul style="list-style-type: none"> 1500 schools (primary and secondary) SET (in particular IT) teachers and students 	<ul style="list-style-type: none"> better education, better teachers will increase uptake time frame 1-5 years 	<ul style="list-style-type: none"> in June 2004 by ministry and bureau of statistics

measure	period	Objective	level	means	target	Expected effects	Evaluated (and effects)
Decreto 279-99	1999 - now	<ul style="list-style-type: none"> - increase research in the industrial private sector. - increase mobility of researchers (into private sector) - create more post-doc research places - encourage R&D in private sector 	national	<ul style="list-style-type: none"> - financial: private scholarships; subsidy and tax exemption for positions for 2 years; maximum 4 positions per company - Financial: tax exemption for 60% of scholarship if company sponsors PhD place 	<ul style="list-style-type: none"> - 6 economic sectors (service, transport companies, industry, S&T parks) - post grad S&T for applied and fundamental research - creating new jobs for researchers outside public domain 	<ul style="list-style-type: none"> - by providing financial incentives and tax exemptions for companies starting new positions in R&D will lead to more jobs in private sector 	<ul style="list-style-type: none"> - not included
Women in engineering professions	2002 - now	<ul style="list-style-type: none"> - low female enrolment in engineering 	local and institute (Torino)	<ul style="list-style-type: none"> - financial: 200 one time grants of €900 and tutoring for first year female students - €180,000 /yr 	<ul style="list-style-type: none"> - 200 female students/yr; tertiary level ; Aerospace Engineering, Electronics, Electrical Engineering, Mechanical Engineering, Computer Engineering, Telecommunication Engineering - time frame: immediately 		<ul style="list-style-type: none"> - no but in first year 260 female students have applied for the scholarship, 2 have been excluded and 58 could not be given a grant due to the limited number of grants
Re-entry of scientists into Italy	2004 - 2009	<ul style="list-style-type: none"> - counter brain-drain by stimulating re-entry of scientists living abroad and - stimulating research and S&T in Italy – creating career opportunities in Italy 	national	<ul style="list-style-type: none"> - financial: 5 year tax relief for scientist and research positions filled by returning professionals 	<ul style="list-style-type: none"> - expert Italian professionals initiating research/scientific work in Italy before 2009 	<ul style="list-style-type: none"> - tax relief would make the entry in Italy more attractive to renown scientists and that this would stimulate the high profiled research in Italy, which in turn will attract more scientists to return - time frame: not given 	<ul style="list-style-type: none"> - no

	measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
Ir	Task Force on Physical Science	2000-?	<ul style="list-style-type: none"> - counter low uptake of SET on all levels - counter low grades on leaving certificates - encourage shift towards SET in education - increase awareness of SET and career options - change attitude, perception of SET 	national, regional, local	<ul style="list-style-type: none"> - regulatory: Improve science education on all levels (€178 million with €66 million yearly for curriculum reform etc) - facilitative: improve access; level; didactics, content, assessment - improving facilities - improve teacher training - Promotion of science careers - reallocation of priorities at school management level - partnerships between schools and private stakeholders in Irish science - revised SET junior cycle - emphasis on practical work 	<ul style="list-style-type: none"> - primary, secondary and tertiary schools (detailed targets per level) - SET (life sciences, physical science and engineering) - teachers, students (overall and by gender) 	<ul style="list-style-type: none"> - time frame first results 1-5 yrs - improving the image of SET will increase uptake - based on case studies major drivers are <ul style="list-style-type: none"> o priority of SET in school management o active involvement of stakeholders in (primary) education o experiences in lower secondary school defines choices: junior cycle needs revising o emphasis on practical work improves uptake 	<ul style="list-style-type: none"> - no
	Leaving Certificates Vocational Program (LCVP)	Not stated	<ul style="list-style-type: none"> - low uptake SET - encourage shift towards SET 	national, regional, local	<ul style="list-style-type: none"> - curriculum reform - creating practice places 	<ul style="list-style-type: none"> - secondary school - SET - give a strong vocational dimension to leaving certificates 	<ul style="list-style-type: none"> - premises: skills are better taught in practice, and in a learner centred approach - time frame is not given - students will <ul style="list-style-type: none"> o realise SET potential o increase self-confidence o improve skills and attitudes – learning from adults they interact with o explore career and business opportunities during their education o learn how to achieve set goals 	<ul style="list-style-type: none"> - no - questionnaires have been developed to assess the changes and the effects; inspectors evaluate the implementation and the results/effects

measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
Chemistry and Physics Intervention project	1985	<ul style="list-style-type: none"> - low uptake SET - encourage shift towards SET as education and career - increase awareness of SET - attitudinal change 	national	<ul style="list-style-type: none"> - curriculum reform - access 	<ul style="list-style-type: none"> - girls in secondary education - SET (physical sciences) 	<ul style="list-style-type: none"> - introducing more practical oriented science curriculum will increase uptake of girls in secondary education, perhaps even in upper secondary cycle - time frame not given 	<ul style="list-style-type: none"> - girls now outperform boys in chemistry, physics and junior science - In general a decrease in uptake of chemistry and physics, since the intervention the boy-girl ratio is now <ul style="list-style-type: none"> o 1:1 chemistry o 1:3 physics (up from 1:4)
Post graduate stipends and salaries	1993	<ul style="list-style-type: none"> - unattractive salaries and opportunities in SET - low SET enrolment - encourage shift to SET - encourage creation of post doc options - improving image of science 	national	<ul style="list-style-type: none"> - earmarked funds (student financing) - improve (competitive) salaries (>€20,000 per annum per post) - tax legislation 	<ul style="list-style-type: none"> - tertiary graduates and post graduates - SET - labour market in <ul style="list-style-type: none"> o Education o Applied R&D o Applied technology o Applied engineering 	<ul style="list-style-type: none"> - time frame not given - better salaries will counter the outflow of SET graduates to other careers and other countries - better opportunities for SET careers will improve uptake 	<ul style="list-style-type: none"> - not available - there is insufficient information on national salaries and career developments. A national database would facilitate evaluation, so it is recommended that stakeholders collaborate in constructing/collecting this data
IT2000	1997 - 2000	<ul style="list-style-type: none"> - improve IT skills - increase awareness S&T options - integrate ICT into teaching and learning in Irish schools at both primary and post-primary level 	national	<ul style="list-style-type: none"> - facilitative: Infrastructural development (60,000 computers and internet in 4100 schools); - teacher training initiative: teacher training (20,000) - pilot research projects - ScoilNet: Web-based service + - interactive software: software review and development to meet needs of teachers - software development for pupils with special educational needs - internet connection (sponsor Eircom) - curriculum reform - £55 million over 3 years 	<ul style="list-style-type: none"> - primary and secondary education - teachers - time frame 1-5 years 	<ul style="list-style-type: none"> - technology supports (if not drives) educational innovation - successful ICT implementation depends heavily on staff competencies and teachers will use innovations/technologies if these are successful - equal access (through school) will prevent IT-divides to occur - ICT will lead to higher academic standards 	<ul style="list-style-type: none"> - case study of 10 schools, 6 previously non ICT. - schools clearly require more time to successfully integrate ICT - where good practice exists, positive school leadership, the presence of an effective IT specialist and the availability of professional support and guidance have been important factors in its development - there remain many additional services and support which need to be put in place - additional funding through to 2002

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	measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
Ge	Junior professor	2002 -?	<ul style="list-style-type: none"> - counter brain drain - create post doc options - create long term research base 	national	<ul style="list-style-type: none"> - financial :earmarked funds for post doctorate positions (€180 million for 4 yrs) 	<ul style="list-style-type: none"> - post graduates - post doc scientists - labour market for education, R&D and fundamental and applied research 	<ul style="list-style-type: none"> - to reduce number of scientist leaving Ge (1 in 7 leave, and excellent Ge scientist work in the US) - timeframe is unclear - 3000 scientist in 4 years 	<ul style="list-style-type: none"> - not evaluated yet
	Bildungskredit	2001 -?	<ul style="list-style-type: none"> - counter drop out overall - increase enrolment overall 	national + regional (Länder)	<ul style="list-style-type: none"> - financial: Student financing (€7,200 per Educational phase or €300 per month – total not given) 	<ul style="list-style-type: none"> - tertiary students - low income students in particular 	<ul style="list-style-type: none"> - credit allows students not supported by BeföG to finish education (not drop out for financial reasons) - timeframe unclear 	<ul style="list-style-type: none"> - evaluation in summer 2004
	Green Card	2000-2004	<ul style="list-style-type: none"> - insufficient supply of SET graduates - insufficient IT skills 	national	<ul style="list-style-type: none"> - regulatory: active recruitment and import of scientists, professionals 	<ul style="list-style-type: none"> - professional in house training (industry) - IT skills - labour market: Applied technology 	<ul style="list-style-type: none"> - increase of professionals will increase Germany's industrial base - time frame not given 	<ul style="list-style-type: none"> - limited evaluation underway: only data on application available (15,110 Green Cards have been awarded, 27% to Indian nationals – probably IT specialists) - unfilled IT vacancies have dropped from 46% in 2001, 41% in 2002 to 12.5% in 2003

	measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
UK	WISE (Women into Science and Eng Campaign)	1984 - now	<ul style="list-style-type: none"> - increase enrolment attract more women/girls to SET (education and career) - counter drop out - increase awareness of barriers for women in SET - attitudinal change wrt SET 	national	<ul style="list-style-type: none"> - facilitating structures, knowledge sharing, etc. - WISE committees (cater for women's needs in UK countries) - information access: Media campaign, brochures, posters, websites - courses and presentations - continuous reaffirmation/ campaign - collaboration with other organisations (such as PSETW) 	<ul style="list-style-type: none"> - women, girls - students (secondary, tertiary and post grad) - professionals - all Educational organisations - all Private organisations (industry etc) - all economical sectors 	<ul style="list-style-type: none"> - Increased awareness of the options and opportunities for women to pursue a career in SET will lead to a greater pool of women considering SET and so to a larger participation - Awareness of barriers for women in SET will help initiative to counter these barriers and counter drop out. 	<ul style="list-style-type: none"> - not officially evaluated - acknowledged effect on female participation in SET (in 1984 only 7% of engineering students were female, in 2000 this is doubled to 15%)
	Headstart	1991 - now	<ul style="list-style-type: none"> - increase enrolment and careers in SET - increase awareness of SET opportunities - to decrease drop out by improving student decision making wrt the choice of university subject/degree 	national local	<ul style="list-style-type: none"> - facilitating structures, knowledge sharing, etc. - summer school programme (week courses at universities)-> information access (interactive en mentoring) - £350/student = £315k/yr paid by students, rest from Dpt of Trade and Industry, Educ and Skills and trusts and funds. Total is unclear 	<ul style="list-style-type: none"> - students already interested in tertiary SET, but unsure on which discipline/subject - secondary students in SET and engineering in particular (preparatory students) - 900 students/yr - 480 schools - 26 educational institutes and 23 industrial organisations 	<ul style="list-style-type: none"> - participation in summer school will help students to determine the 'best' study for each - participation gives a first feel of undergraduate life and will motivate students to continue - time frame unclear/not given - gains in contacting excellent students early so <ul style="list-style-type: none"> o bursaries and sponsorships are more effective o identify candidates for industry o raise company profile o increase links with educational system/ schools/universities etc. 	<ul style="list-style-type: none"> - not formally evaluated - 88% say headstart strengthened their decision to pursue SET or engineering - 86% declare engineering of science based career as first job choice - 26% are young women, 16% from minorities - 90% have 8+ A to C passes for GCSE or standard examinations (better students) - 63% of headstart students are reading MEng courses

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measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
Promoting SET for women Unit PSETW	1994 - now	<ul style="list-style-type: none"> - counter decreasing female participation in SET at every level (choice of courses, A-levels, first degree and on to career) - increase enrolment and careers in SET - increase awareness of SET opportunities - encourage shift to SET - attitudinal change wrt SET - improving recruitment and career development - involve women in SET policymaking - structural change within S&T 	national regional	<ul style="list-style-type: none"> - facilitating structures, knowledge sharing, etc. - information access: Media campaign, brochures, posters, websites - personal (mentor, role models) - courses and presentations - information is targeted at different age groups <ul style="list-style-type: none"> o before A-levels (14-16) o after A-levels (18-19) o after BSc (22/23) o young mothers returning to labour market - information gathering on status (statistics, etc) - costs unclear 	<ul style="list-style-type: none"> - all levels (ISCED 1 to 6 + prof training and life long learning) - female students/ graduates etc. - extra attention for <16 (before choice at secondary level) - all sectors of labour market (with SET focus) <ul style="list-style-type: none"> o career and return options o life planning 	<ul style="list-style-type: none"> - promotional actions will increase awareness of opportunities and barriers for women in SET, which will lead to a shift towards SET, better informed choices and less drop out - creation of knowledge sharing platforms will facilitate entry and re-entry of women in SET careers and support career development - information on status and development wrt to female participation in SET at all levels will support the aims - time frame 1 – 12 yrs 	<ul style="list-style-type: none"> - evaluated in 1997 and 2000 - info on results requested

	measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
	Specialist Schools Programme	1994 - now	<ul style="list-style-type: none"> - better match education in skills and demand from labour market - improve quality of teaching - increase local involvement through links with local industry 	national	<ul style="list-style-type: none"> - regulatory: school infrastructure and curriculum reform; schools each specialise in one or two of 10 specialities (arts, business & enterprise, engineering, humanities, language, mathematics & computing, music, science, sports and technology) - cost for the school £100.000/school + £50.000 sponsoring + £126/pupil 	<ul style="list-style-type: none"> - half of all secondary school pupils - 1444 schools in the UK, up to 54% 	<ul style="list-style-type: none"> - through specialisation / focusing on one or two major subjects, increase the level of education as well as the achievements of pupils - improve quality of specialist skills by cooperating with partner schools in the area - increase communication between education and industry on required skills - time frame: school generation 	<ul style="list-style-type: none"> - in 1998 through questionnaires (300+ schools) and inspections - focus on attainment, role in local environment and good practices - level of A-C grades per speciality is higher - in GCSE also higher grades for speciality courses - broader choice of courses - the community dimension (working with local industry etc) was weak

measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
SETNET	1996- now	<ul style="list-style-type: none"> – encourage a flow of well motivated, high quality people towards engineering and related subjects – aim at structural change in policy and SET – increase communication between teachers and learners of SET – improve SET teaching – increase awareness of S&T options – increase involvement of industry in developing campaigns 	local on a national scale	<ul style="list-style-type: none"> – facilitating structures, knowledge sharing, etc. by creation of 53 SETPOINTS <ul style="list-style-type: none"> – focal points for collaboration between teachers, business and industry. – information access: Media campaign, brochures, posters, websites – personal (mentor, role models) – SE Ambassadors visit schools and explain to young people the importance of science to everyday life <ul style="list-style-type: none"> ○ Supporting out-of-school activities/competitions ○ Mentoring groups ○ Acting role models ○ Supplying schools/education with industrial experience – teacher training and curriculum support – Attitudinal change – £2M/yr to SETPOINTS, with additional £2.3M/yr over 2 to 3 yrs to local delivery of SET initiatives through SETPOINTS (0.3M/y for Science and Engineers Ambassadors) 	<ul style="list-style-type: none"> – primary and secondary SET teachers and students – ambassadors visit schools and explain to young people the importance of science to everyday life <ul style="list-style-type: none"> ○ Supporting out-of-school activities/competitions ○ Mentoring groups ○ Acting role models ○ Supplying schools/education with industrial experience 	<ul style="list-style-type: none"> – providing teachers and students with a physical contact point where they can get all relevant information quickly and without fuss. This will increase the likelihood that they don't miss important issues – industry and business can avoid overlap by using the centralized information system to target a population/group – time frame is not given 	<ul style="list-style-type: none"> – not being evaluated – acknowledge effect on information to teachers etc. – SEA (SE Ambassadors) is considered a success and backed by (large) companies.

measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
ATHENA (part of larger set)	1999 - now	<ul style="list-style-type: none"> - Increase female participation in SET in HE - Increase number of females in high posts 	natioanal and local	<ul style="list-style-type: none"> - facilitating structures, knowledge sharing, etc.: increasing knowledge of barriers for women in SET and in HE - funding from educational organisation (univ. principals, education councils etc) - funding of dedicated money from DTI, Office of Science and Technology - ear marked funds - financial: Awards for HE institutes to develop structures to increase women participation in SET in HE (mentoring etc) - funds: not given, info requested 	<ul style="list-style-type: none"> - females seeking SET related work in HE - HE institutes (30) - 5000 students/yr, tertiary level - policies on career and return options, secondary working conditions, life planning facilities - procedures and barriers to career development for women towards high posts in HE - time frame 1 to 12 yrs 	<ul style="list-style-type: none"> - increasing knowledge of differences between male and female career paths will help change processes and reduce infrastructural barriers for women - improving incentives for organisations to change towards a more female friendly organisation: <ul style="list-style-type: none"> o comfort factors (secondary work conditions) that attract or retain women o how to start the development o what changes work best 	<ul style="list-style-type: none"> - first evaluation completed in 2003 (period 1999 – 2002, three objectives) - women in SET: provided support to, countered isolation of and increased awareness of women in SET, the difference in career development and barriers experienced by women. The mentoring network seems to be highly effective in short time scale - working in SET: aimed at awareness of barriers in the organisational structure of SET in HE: HEI seem to realise the role the structure plays and are considering change - good practices of projects: <ul style="list-style-type: none"> o none of projects were isolated – had champions in senior managers, heads of dept and women scientist o monitoring was essential o feedback on progress women’s representation in SET

measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
Everything you wanted to know	?	<ul style="list-style-type: none"> - Increase awareness of opportunities to study science - Information on financial support and work opportunities in SET - Improve links between students HEI and business 	national	<ul style="list-style-type: none"> - facilitating structures, knowledge sharing, etc.: central easy to access and comprehensive website (with hard copy version as well) 	<ul style="list-style-type: none"> - upper secondary students and beginning tertiary students (ISCED 5 and 6) - time frame is 0 to 12 yrs 	<ul style="list-style-type: none"> - more information will increase well informed choice and perhaps a shift towards SET or at least less drop out due to financial reasons or wrong choices - links between students, HEI and business will improve image? 	<ul style="list-style-type: none"> - not found, scheme contacted for information
Highly Skilled Migrant Programme	2002 - now	<ul style="list-style-type: none"> - Increase supply S&T professionals by import of foreign scientists and retaining foreign students within UK - Information access: improving awareness of opportunities to import S&T prof. 	national	<ul style="list-style-type: none"> - regulatory: labour market access - simplifying access and work permit for scientists, SET professionals - regulatory: retaining foreign students within UK - costs seem limited 	<ul style="list-style-type: none"> - UK employers - foreign scientists and students (65000) - SET focus 	<ul style="list-style-type: none"> - time frame: not given, but estimated at 1-5 years - simplifying access and work permit procedure will attract scientists wishing to work in the UK - simplifying work permit regulation for foreign students will retain them for UK work 	<ul style="list-style-type: none"> - not well known enough - 90% of requested work permits are processed within 1 day - employers claim recruiting abroad is easier now - effects will take several years to enter statistics

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Investing Human Capital	2003-2006	<ul style="list-style-type: none"> - increase number of S&T post doc opportunities - improving post doc career and study programmes by higher salaries and stipends; 	national	<ul style="list-style-type: none"> - financial: increase stipends to £12k and higher where recruiting is critical/difficult - financial: increase pay research council post doc's by £4k by 2005 - regulatory: provide opportunities to extend PhD periods (up to 3.5 yrs) - facilitating: creating 1,000 new 5-yr academic fellowship posts - increasing to £100million/yr 2005 	<ul style="list-style-type: none"> - post graduates (ISCED 6) - potential PhD students and post doc 	<ul style="list-style-type: none"> - better financial rewards will improve the competitiveness of SET as a career and retain students/post docs - time frame 1-5 yrs - increase in quantity and quality of PhD and post doc positions, in particular in SET and math - by higher quality, innovation strength will be stimulated 	<ul style="list-style-type: none"> - no and too early to see results
Student Associate Scheme (SAS)	(2000 predecessor) 2003 - 2006	<ul style="list-style-type: none"> - facilitates students to teach and explore teaching as a career - improve S&T teaching at school - improve teacher/student ratio in school - increase communication between HE and SE - increase high quality teachers for SET: career options 	national and local	<ul style="list-style-type: none"> - facilitative: improving student teacher ratio in SE - facilitative: creating practice places for tertiary students - regulatory: 	<ul style="list-style-type: none"> - 47 educational organisations - improving secondary education – targeting SE pupils - targeting tertiary students 	<ul style="list-style-type: none"> - exposing students to experiences as teachers can improve the image of education as a career - experience improves the choice of students considering teaching and lowers drop out - improving quality of SET in school will increase inflow in A-levels, and beyond. (trickling down effect) - time frame not given 	<ul style="list-style-type: none"> - too early to tell - pilot projects were evaluated favourably by students; it is unclear if the scheme relieved teachers of some of their tasks or made pupils more enthusiastic about S&T subjects
measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)

	measure	period	objective	level	means	target	Expected effects	Evaluated (and effects)
Sw	SciTech Basis Year	1992 - now	<ul style="list-style-type: none"> - increase enrolment S&T in general - encourage shift towards S&T 	national	<ul style="list-style-type: none"> - regulatory: Creating alternative route to S&T HE; better qualifier courses 	<ul style="list-style-type: none"> - secondary and tertiary level - SE graduates and HE entrants with insufficient S&T skills - teachers 	<ul style="list-style-type: none"> - pupils with insufficient science skills will after this course proceed into S&T HE. This will mean higher enrolment and perhaps increase female participation - time frame: not given 	<ul style="list-style-type: none"> - in 2001 31 schools offer this, 50% of enrolees is female and 75% proceed into S&T HE - no info on graduate yet
	SciTech (NOT)	1993-1998 and 1999-2003	<ul style="list-style-type: none"> - increase enrolment in general - attitudinal change in young people - improve preparatory skills for S&T in HE - improve curriculum 	national	<ul style="list-style-type: none"> - facilitative: Teacher training 	<ul style="list-style-type: none"> - primary and secondary education pupils and teachers - parent and community enrolees for SE S&T programme 	<ul style="list-style-type: none"> - increase enrolment overall, with perhaps 2nd chance for women 	<ul style="list-style-type: none"> - 15% increase overall, with 20% increase in women
	National Resource Centres	1994 (chem.) 2002 (biotech)	<ul style="list-style-type: none"> - increase enrolment S&T in HE by improving interest for S&T - improve quality of S&T in primary and secondary education 	national	<ul style="list-style-type: none"> - facilitative: improving teacher training, 	<ul style="list-style-type: none"> - primary and secondary teachers - life sciences, physical science and mathematics, chemistry and technology 	<ul style="list-style-type: none"> - increased recruiting of students from upper secondary school to HE - time frame not given 	<ul style="list-style-type: none"> - not officially evaluated but ranked better than expected (3-4) on scale 1-5.