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Stimulating Science and Technology in Higher Education

An international comparison of policy measures and their effectiveness

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Prepared for the Dutch Ministry of Education, Culture and Science

RAND EUROPE

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Summary

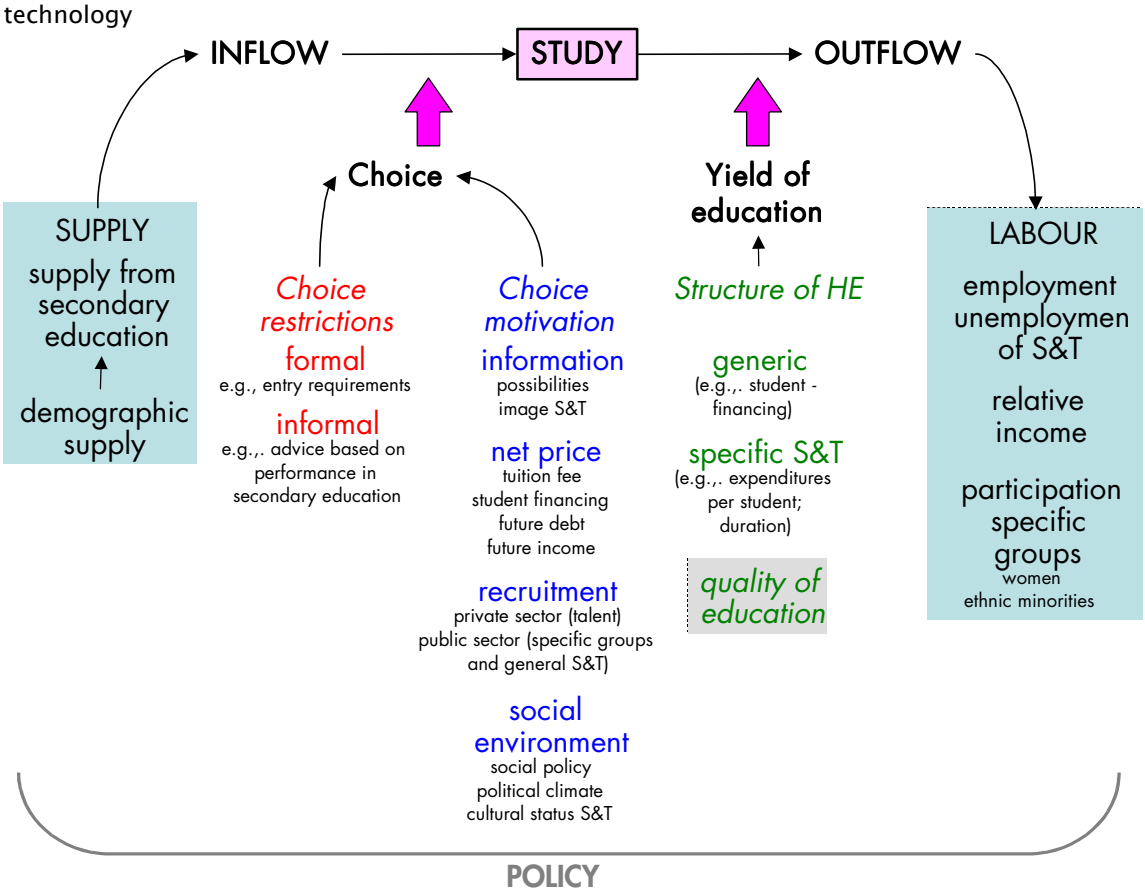
The long-term goal for Europe to become the world's leading competitive and dynamic knowledge economy was formulated at the Lisbon summit in 2000, and affirmed and specified in more detail in the following Barcelona summit. However, there is an increasing shortage of scientists in Europe, and surveys 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



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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, one 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.