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STRATEGIC SCIENCE

As the Prime Minister stated[1] in November this year "science will be as important to our economic future as stability." Indeed, science, technology, engineering and mathematics (STEM) were among the higher education (HE) subjects identified in 2005 as being strategically important and vulnerable.[2] Set against this background are downward trends in the numbers of students studying certain STEM subjects and closures of STEM departments in UK universities. This POSTnote outlines trends in STEM education and the possible reasons for them, and looks at their significance in terms of supply and demand of STEM qualifications. It also examines issues concerned with closures of university STEM departments.

Background

In 2002, the Roberts Review of the supply of STEM skills in the UK[3] highlighted an increasing demand for high-quality STEM graduates. It concluded that a shortfall in science skills could harm innovation. The government's *Science and Innovation Investment Framework 2004-2014*[4] included a commitment to increase public and private investment in research and development (R&D) from 1.9 per cent of GDP to 2.5 per cent by 2014. It was followed up in March 2006 with the *Next Steps*[5] document which set a series of targets. These aim to ensure a strong supply of skilled scientists, engineers and technologists and a scientifically literate public that is able to understand the benefits and risks of emerging technologies. There is no clear understanding, however, of how many STEM-qualified people the UK needs.

Trends in STEM study

A-Level entries

Since 1992, the number of A-level entries in all subjects has increased by 10%. This expansion is not reflected across the sciences. For example:

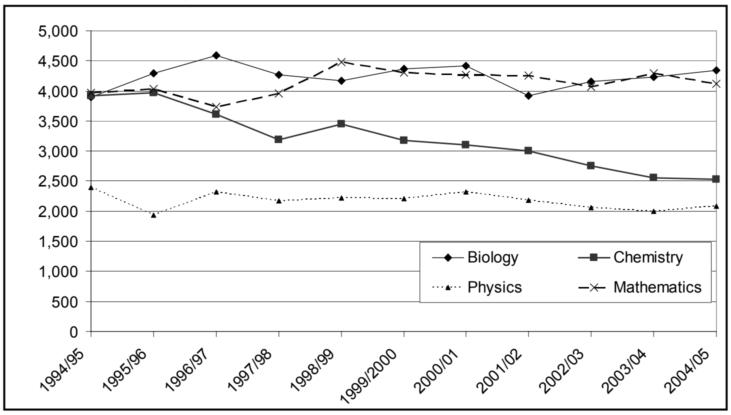
- there has been a **decrease** in A-Level entries to physics (34%), maths (13%) and chemistry (6%);
- and an **increase** in biology entries by 13%.

Since 2002 there have been slight increases in entries to chemistry and maths but the numbers remain considerably lower than in the early 1990s.

Higher education (HE)

While overall participation in HE has been growing, the numbers of physics, biology and maths graduates have remained fairly stable between 1994/95 and 2004/05. In the same period there was a 35% drop in the number of chemistry graduates (Figure 1). A large overall increase in biological sciences graduates had been reported but this is attributable to growth in subjects other than pure biology. For example psychology accounted for 47% of this grouping in 2004/5, up from 33% in 1994/5. First degree graduations in the engineering disciplines have also remained reasonably stable over this period.

Figure 1. First degrees obtained in science and mathematics by UK domiciled students



Source: These figures come from a re-analysis of data commissioned from the Higher Education Statistics Agency (HESA) by the Royal Society for their October 2006 report[6] into STEM HE. The way in which HESA categorises students has changed but the re-analysis uses the same course definitions as far as possible throughout the period. It shows that the recent apparent large rise in maths and biology graduates arose from the way students were classified.

There are some signs of a turnaround in chemistry with an increase in entries onto degree courses over the last three years. 2006 saw 3,581 acceptances of first-year places, the highest number since 1999 and up 18% since 2003.

Factors behind the figures

There are several factors which may contribute to the decline in students choosing certain STEM subjects.

Teaching

There is a shortage of teachers with specialist qualifications in particular sciences. A report in January 2006 by the National Foundation for Educational Research showed that:

- 44% of all secondary science teachers in England in 2004-5 were biology specialists;
- only 25% and 19% held a specialist qualification in chemistry and physics, respectively;
- 24% of mathematics teachers were non-specialists.

This imbalance was more pronounced in 11-16 schools, where 1 in 4 schools had no physics specialists. Schools may be more likely to use specialists to teach A-Level classes, so a higher proportion of GCSE students may be taught by non-specialists than even these figures suggest. There is concern that non-specialists may be less likely to show the enthusiasm, flair and confidence to inspire their students to choose STEM options at school and beyond. The resultant shortage of STEM graduates impacts further on the teaching shortage.

In November 2006, a House of Lords Science and Technology Select Committee inquiry[7] stressed the importance of good-quality practical work in capturing pupils' imagination. The shortage of specialist teachers, along with curriculum pressures and health and safety fears means fewer teachers are willing or sufficiently confident to teach practical classes. The government confirmed in March 2006 that it will not deliver the £200 million for school science laboratories that it pledged in the 2005 General Election. This was criticised by the Committee which heard evidence of the unsatisfactory state of many school facilities.

The image of science and scientists

Science and mathematics compete with other subjects that many young people may see as more fashionable or engaging. Pupils sometimes think school science is too reliant on repetition of a large volume of abstract information, and not relevant to contemporary life or media coverage of scientific issues[3]. Other research suggests young people are positive overall about the benefits of science and technology but have concerns about ethics in science.

Perception of science as a 'harder' subject

The sciences and maths are among the most difficult A-Levels. Students who take sciences and maths at A-level achieve lower average grades in these subjects than the average student with equivalent GCSE results. Students focussing on university entry to non-STEM subjects may be less likely to take science or maths in order to gain a higher score.

Careers advice

The House of Lords inquiry heard evidence that many young people have no real idea of what a scientist does and that 90% of school careers advisors did not feel confident giving advice about STEM careers.[7] Students may thus not be aware of the diverse and rewarding career paths that can lead from STEM qualifications. These include sectors outside traditional STEM professions which contribute to graduates in physics and chemistry, for example, earning more than average. Many organisations produce materials to promote STEM careers amid a bewildering choice of other subjects. The Science Council is developing a *Careers From Science* website which would act as a 'one-stop-shop' for STEM career advice. DfES announced funding of £0.5m for this project in December 2006.

Closures of university departments

Extent of closures

The House of Commons Science and Technology Select Committee[8] heard that the rate of closures of university STEM departments has increased since 2001, and more are expected (Box 1). Once a department has been closed, re-opening it can be very expensive. There are concerns that closures may create 'deserts' in certain regions of the UK where there is no HE provision of key subjects. This risks excluding people in these areas who need to study close to home for financial, family or cultural reasons.

Box 1. Changing UK provision in STEM HE

- **Physics**: There were 48 UK institutions offering physics degrees in 2005. This is 31 fewer than there were in 1994. The University of Reading announced that its physics department is to close in 2010.
- **Chemistry**: 55 departments currently teach chemistry in the UK; since 1996 26 universities have ceased to offer chemistry degrees. Among these are Kings College London and University of Exeter. University of Sussex chemistry department was saved from closure in 2006.
- **Mathematics**: There were 46 Maths departments in 2005; 5 have closed since 1999, most recently at the University of Hull in 2004.

Why are STEM departments closing?

Vice-Chancellors' decisions to close STEM departments have generally been taken for financial reasons. Science and engineering are expensive to teach because of the amount of laboratory work required. The Institute of Physics (IOP) and the Royal Society of Chemistry (RSC) recently examined the costs of ten physics and eight chemistry departments. They found that all had significant budget deficits when the costs are compared with the funding received from the Higher Education Funding Council for England (HEFCE, Box 2) and other sources. These analyses do not, however, consider the deficits relative to funding received by other disciplines. Currently the shortfall is balanced by subsidy from research or teaching of other subjects within each HE institution (HEI). The RSC estimates that the total deficit across UK chemistry departments is about £100 million. Extrapolating these data across the physical sciences and engineering, RSC suggests that £306 million is needed each year to secure the future provision of laboratory-based subjects.

Box 2. How government funds HE

The total grant to be allocated to all HEIs is decided in the budget. In 2006/7, this was £6,706 million. The Higher Education Funding Council for England (HEFCE) decides the distribution between teaching, research and other funding, then determines how this total should be divided between all HEIs. Scotland, Wales and Northern Ireland have similar HE funding councils.

In calculating teaching grants for individual HEIs, HEFCE takes into account the previous year's allocation, and also the student profile, considering the following factors:

- number of students;
- student-related factors (e.g. part-time or students on long courses or foundation degrees);
- institution-related factors (e.g. London weighting);
- subject-related factors.

Subject-related factors take into account the increased cost of teaching some courses, including laboratory-based subjects which carry a weighting factor of 1.7 for every student. For comparison clinical stages of medicine, dentistry and veterinary courses carry a weighting of 4; subjects with a studio, laboratory or fieldwork element receive a weighting of 1.3. These are relative to all other subjects which have a factor of 1. The funding method is being reviewed but any increase in weighting for science would mean other subjects receiving reduced funding.

Once the allocation for each HEI has been calculated, it is awarded as a block grant. The HEI is then free to distribute the grant between its own departments however it sees fit.

Issues

Issues pertaining to STEM literacy, education, qualifications and careers are discussed below.

Stem graduates

Supply and demand

There is a consensus that good quality STEM graduates are in high demand in R&D. Traditional STEM careers face competition from other professions. In the financial and business sectors, for example, the analytical, numeracy and problem-solving skills of STEM graduates are sought-after and more attractive salaries are offered.

The Department for Trade and Industry (DTI) stated in March 2006 that the current supply of graduates is adequate for current trends in employment. However, the government's commitments to increase R&D investment may cause an increase in demand.

Conversely, the Confederation of British Industry (CBI) estimates that 2.4 million additional people with STEM skills will need to enter the workforce between 2004 and 2014, although not all of these will require degrees. This forecast uses data published in an analysis of the future pattern of skills demand in the UK[9]. It is based on recent employment trends by occupation and takes into account the numbers expected to leave the labour market (by retirements, for example). The Engineering Council estimates that between 75,000 and 100,000 Chartered Engineers will retire in the next 10-15 years while only around half that number will begin their career in that time. It is thought retirement will also contribute to a particularly high net demand for teaching and research professionals.

Professional organisations are in a position to assess the skills needs of individual industries. For example, the Association of the British Pharmaceutical Industry (ABPI) asked its membership in 2005 to identify current and future shortages in skills areas[10]. Among those skills identified as high priority were analytical and physical chemistry as significant recruitment was occurring in these areas from outside the UK. There is scope for improved dialogue between industry and universities so the needs of employers can better be met. The growth in small, niche businesses in particular will require continued links with HE. However the unpredictable nature of industry makes it difficult to tailor the curriculum. The government has set up Sector Skills Councils (SSCs) to represent the regional and national skills needs of UK industry at a strategic level. For example Cogent, the SSC for chemicals, nuclear, oil and gas, petroleum and polymers has identified a shortage in technician-level skills.

Quality of STEM graduates

Consultations with employers tend to focus on the quality of STEM graduates more than the quantity. The House of Commons Science and Technology Select Committee has noted that it is not sufficient simply to increase the numbers of graduates while better practical skills and depth of knowledge remain sought after by employers[11]. An increase in the number of different types of science degrees adds to the variation in graduate quality. Meanwhile core STEM graduates who also have skills such as communication and teamwork are reportedly hard to find.

Research careers

The government has improved the attractiveness of research careers by raising the PhD stipend to a minimum of £12,000 in 2005/06. However job security remains an issue for R&D professionals. Especially in academe, short funding cycles dictate length of contracts and often necessitate changing institutions regularly. This affects women and those with families in particular.

STEM in schools

Encouraging young people to study STEM

The *Next Steps* targets include yearly increases in the numbers of A-level students in physics, chemistry and maths to re-attain the levels seen in the early 1990s. Improvements were pledged in Key Stage 3 and GCSE achievement. Changes to the GCSE science curriculum have been implemented from September 2006, following criticism that it was too focussed on the needs of future scientists rather than the general population. The aim of the new curriculum is to balance a sound knowledge base with an appreciation of the scientific process and contemporary scientific issues. It contains a greater choice of applied elements to develop scientific literacy while still encouraging further study. In most cases students will study for two science GCSE awards. The programme of study could however be completed as a single award and opportunities exist to study the three sciences separately.

Recruiting specialist science teachers
Next Steps also sets targets for a change in recruitment and retention of specialist physics, chemistry and maths teachers. Progress in these areas will be published annually, with July 2006 seeing the first such report of baseline data. Financial incentives are offered by Department for Education and Skills (DfES) in order to tempt more STEM graduates into teaching. From September 2006 the Teacher Training Bursary of £9000 is available to trainees on postgraduate certificate of secondary education (PGCE) courses in science and mathematics. A 'golden hello' of £5000 is also payable on gaining qualified teacher status in science or maths. Smaller bursaries apply for other subjects.

Supporting non-specialist science teachers
The RSC, IOP and the Science Learning Centres have developed resources and training schemes to improve the knowledge and confidence of non-specialist science teachers. However this type of subject-specific continuing professional development is not compulsory, which may be an obstacle to the success of the schemes.

Co-ordinating STEM initiatives
In 2004, DfES identified over 470 initiatives funded by governmental and external agencies aimed at increasing supply of STEM professionals and promoting STEM literacy. Inevitably many of these have duplicate objectives. DfES has set up the STEM Strategy Group to evaluate and coordinate these schemes and provide a more coherent delivery for the same amount of money[12].

STEM capacity
The recent closures of university chemistry and physics departments have raised issues over the UK's future capacity to produce graduates in these subjects, particularly in view of the targets for increased HE participation in STEM subjects. HEFCE, DfES, and ministers are reluctant to micro-manage HEIs. They see the priority as maintaining or increasing overall HE STEM capacity at regional and national level, rather than ensuring the survival of any particular department. Currently, if an HEI is considering closing a science department then the vice-chancellor is required to alert HEFCE and DfES at this early stage. These bodies will collaborate with the HE providers to prevent the closure or to transfer capacity to other HEIs in the region. For example, in 2005 HEFCE funded the transfer of students from the University of Exeter chemistry department to the Universities of Bristol and Bath enabling an overall increase in chemistry provision in the south-west. In closing its chemistry department, Exeter was able to strengthen its physics department.

However, there are no strict parameters to define 'regional' provision. For example, when the University of East Anglia's school of physics was closed, HEFCE funded staff relocation to the University of Bath, some 230 miles away. Equally, neither HEFCE nor DfES have defined an acceptable minimum level of HE STEM capacity in the UK. An expansion in STEM student numbers is planned but any further closures could result in a system that is unable to cope with increased demand for places. To counter this, HEFCE announced in November 2006 a package of £75 million over three years for vulnerable science subjects. The funding can be used by HEIs to maintain capacity in the short term.

Overview

- Student numbers in certain STEM subjects at school and university are in decline. Science departments in UK universities are closing due to funding shortfalls.
- There is no clear estimate of the national requirement of STEM-qualified professionals, but good quality STEM graduates are in high demand in industry, academe and other sectors. Employers are increasingly looking abroad for STEM graduates.
- The government has pledged to increase spending on R&D, has set targets for step changes in numbers of students and specialist teachers, and has reformed the GCSE science curriculum.
- Further progress requires government, education providers and business working together to improve the attractiveness of STEM qualifications and careers.

Endnotes

1 *Our Nation's Future – Science* Speech to the Royal Society, Oxford, 3rd November 2006
2 http://www.hefce.ac.uk/aboutus/sis/
3 Sir Gareth Roberts, *SET for success*, HM Treasury, April 2002
4 *Science and innovation investment framework 2004-2014*, HM Treasury, July 2004
5 *Science and innovation investment framework 2004-2014: next steps*, HM Treasury, March 2006
6 *A degree of concern?* Royal Society (31/06), October 2006
7 House of Lords, Report of the Science and Technology Committee, Session 2005-06, *Science teaching in schools,* HL 257
8 Science and Technology Select Committee, Second Report of Session 2005-06, *Strategic Science Provision in English Universities: A Follow-up,* HC1011
9 *Working Futures 2004-2014*, Institute for Employment Research, University of Warwick, January 2006
10 *Sustaining the skills pipeline*, Association of the British pharmaceutical industry, November 2005
11 Science and Technology Select Committee, Eighth Report of Session 2004-05, *Strategic Science Provision in English Universities,* HC220-1
12 *STEM Programme Report*, DfES, October 2006

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology.

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