Participation in Science, Engineering and Technology

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Introduction

The Scottish Executive has recently introduced a Science Strategy for Scotland. A key aim of the strategy is to "ensure that enough people study science to a standard which will enable the future needs of the country to be met" (Scottish Executive, 2001). This report describes patterns of participation in science, engineering and technology (SET) by young people in Scotland as they make the transition from school to higher education. It focuses on the cohort of young people who completed the final stage of compulsory schooling in 1998, and follows the progress of those who moved from school to higher education by 2001. It is one of a series of special studies based on the Scottish School Leavers' Surveys (SSLS).

Key findings

- In the final two years of compulsory education (S3-S4) all pupils studied at least one science subject and just over half studied at least one technology subject. Gender and attainment were the main factors that influenced differences in choice of science and technology subjects.
- A fifth of pupils would have liked more help and advice in making their subject choices.
- Two-thirds of young people stayed-on to post-compulsory schooling. Their principal reason for staying on was to gain qualifications that would improve their job prospects.
- In S5/S6, just over half of students studied any science subjects, and a quarter studied any technology. Standard Grade subjects and attainment were key influences on subjects chosen.
- 37% of young people had entered higher education by age 18-19. Almost all gave the reason "I am doing this course so that I can get a satisfying job in the future".
- Having science qualifications boosted chances of entering a degree course. Young people with Higher Grade awards in science subjects were more likely to enter degree-level courses than their peers with the same overall Higher Grade attainment.
- 32% of higher education students were studying SET: 11% mathematics and informatics (includes computing); 10% engineering technology; 6% physical science; and 5% biological science.
- Amongst science-qualified higher education entrants the chances of studying SET were very high: 52% of students with Higher Grade technology were studying SET, as were 48% of those with two or more Higher Grade sciences and 40% of those with Higher Grade mathematics.
- After taking account of attainment and science qualifications, females were less likely than males to study mathematics, informatics or engineering.
- One quarter of students with two or more sciences at Higher Grade were studying medicine and dentistry or subjects allied to medicine. The proportion for science-qualified females was 34%.

Background

Levels of participation in SET in Scotland are relatively higher than elsewhere in the UK (HM Treasury, 2002). Nevertheless, statistics from Scottish Higher Education Funding Council (SHEFC) indicate that levels of participation in some aspects of SET, particularly science and engineering, have not increased to the same extent as overall levels of entry to higher education (SHEFC, 2002). Specifically, participation in engineering has declined, while participation in computing has increased dramatically. Thus suggestions that participation in SET may be problematic relate to relative decline in the strength of demand for courses in biological and physical sciences and engineering. Possible reasons for this decline suggested by other research include:

- negative images of science (Driver *et al.*, 1996; Roger & Duffield, 2000);
- relative difficulty of science subjects (Kelly, 1987; HM Treasury, 2002);
- low status of technology subjects (McCulloch *et al.*, 1985);
- gender differences (Croxford, 2000; Tinklin *et al.*, 2001);
- the system of subject choice in schools (Roger & Duffield, 2000);
- low levels of occupational awareness and careers guidance (Munro & Elsom, 2000);
- problems of student finance (Forsyth & Furlong, 2000; HM Treasury, 2002).

The Science Strategy for Scotland

The Science Strategy for Scotland suggests that participation in SET at school and in post-school education is important for two reasons:

1. to ensure that young people entering the Scottish workforce of the 21st century have the knowledge and skills necessary to promote economic, scientific and technological development;
2. to give the future citizens of Scotland an understanding of scientific and technological approaches and evidence, so that they will be able to make informed decisions on scientific and technological issues.

The Science Strategy includes policies to improve participation in science within school and post-school education related to these reasons. Policies for schools include:

- advice by Learning and Teaching Scotland about "how to ensure that all school pupils have the opportunity to acquire the capacity to cope as citizens and decision makers with scientific issues";
- improved teaching materials and assessment methods;
- additional teachers and greater attention to Continuing Professional Development (CPD);
- improved accommodation and resources for science education;
- activities to promote interest in science.

Policies for post-school education include:

- an analysis by Future Skills Scotland of the supply and demand for people with science qualifications;

- improvements to post-school science courses to enhance generic skills including communication skills;
- improved information and advice about careers.

(Scottish Executive, 2001a, Section 3)

Evidence from the Scottish School Leavers' Survey (SSLS)

This report describes patterns of participation in SET by young people in Scotland as they make the transition from school to higher education. The analysis is based on data from the SSLS and Scottish Qualifications Authority (SQA). It focuses on the cohort of young people who completed the final stage of compulsory schooling in 1998, and follows the progress of those who moved from school to higher education by 2001. The full report of the study was submitted to the Executive in 2002 (Croxford 2002); we are issuing this Briefing now in order to give wider publicity to the issues raised by the research.

Science and technology in S3-S4

National Guidelines for the curriculum ensure that pupils have the opportunity to study science and technology throughout their compulsory schooling. The S3-S4 stages, when pupils study Standard Grade courses, are their first opportunity to choose which subjects to study, which to specialise in, and which to drop. Over a fifth of young people in the SSLS cohort expressed the wish for more help in making these choices. Other studies have emphasised the need for more careers guidance to be provided at earlier stages of schooling in order to help young people to develop their career thinking and make appropriate subject choices (Howieson & Semple, 1996). Research in England has found low levels of awareness of the value of science courses and qualifications to a range of careers (Munro & Elsom, 2000), and it is likely that a similar lack of awareness is a factor in decision-making in Scotland also.

Subjects studied at Standard Grade in 1998 by young people included in the Scottish School Leavers' Survey are summarised in Table 1. All pupils studied at least one science subject at Standard Grade, and one third studied two or more science subjects. Just over half of all pupils studied at least one technology subject.

Choice of subjects varied by gender and attainment. Over half of girls studied biology compared with less than a quarter of boys, with the position reversed for physics. Interestingly, the proportions of females and males studying chemistry were almost equal. Exceptionally strong gender differences were evidenced in technology, with very few girls taking technological studies, craft and design or graphic communication.

High-attaining pupils were most likely to study physics and chemistry, and low-attaining pupils studied (general) science (table not shown). The current general science course is perceived to be an easy option for lower-attaining pupils.

Table 1: Science and technology subjects at Standard Grade in 1998 (% of females and males)

	Females	Males	All
Science subjects			
Chemistry	40	41	40
Biology	52	22	36
Physics	21	45	33
General Science	22	28	25
At least one of the above science subjects	99	99	99
2 or more individual science subjects	32	34	33
Technology subjects			
Computing	24	38	31
Craft and Design	9	34	22
Graphic Communication	6	17	12
Technological Studies	1	15	8
At least one of the above technology subjects	36	78	57
2 or more technology subjects	3	25	14
Core subjects			
Mathematics	99	98	98
English	98	98	98
Sample size (=100%)	*2834*	*2085*	*4919*

The effect of attainment on the likelihood of pupils choosing to study technology subjects was not as strong as the effect on choice of science subjects, but there was a tendency for more high-attaining pupils to study computing, and more low-attaining pupils to study craft and design. In Scottish schools technology and science occupy different modes of the curriculum, and technology has tended to be given lower priority than science. Science is a relatively high-status curricular area with a reputation for being difficult: this is borne out by the evidence that high-attaining pupils tend to study physics and chemistry. On the other hand, many of the technology subjects have inherited the relatively low-status of practical subjects such as metal work and woodwork that tended in the past to be studied by low-attaining males. This is despite the fact that technology courses at Standard Grade cover the full ability range, and provide pupils with understanding and skills that could complement those covered in science courses.

Other factors influencing young people's choice of science and technology subjects in S3-S4 were family background, university aspirations and type of school.

Science and technology in S5-S6

Over two-thirds of young people who completed compulsory schooling in 1998 stayed on to post-compulsory schooling. Almost all (96%) gave the reason "*I thought that by getting better qualifications I'd improve my job prospects*".

In S5 and S6 young people could choose the subjects they wished to study; half of S5/S6 students studied at least one science subject and one quarter studied two or more science subjects. A quarter of all S5/S6 students studied at least one technology subject. These are summarised in Table 2.

Table 2: Subjects studied in S5 or S6 (% of females and males)

	Females	Males	All
Science subjects			
Biology	33	19	26
Human Biology	9	4	6
Chemistry	24	29	27
Physics	16	39	27
At least one of the above science subjects	52	56	54
2 or more individual science subjects	23	27	25
Technology subjects			
Technological Studies	<1	6	3
Craft and Design	4	14	9
Graphic Communication	3	11	7
Computing	7	19	13
At least one of the above technology subjects	13	41	26
2 or more technology subjects	1	8	4
Core subjects			
Mathematics	46	52	49
English	77	68	73
Sample size (=100%)	*2253*	*1612*	*3865*

Gender differences in choice of science subjects were similar to those at S3-S4 described above, but gender differences in study of technology subjects were even stronger. Only 13% of females, compared with 41% of males, studied one or more technology subjects in S5 or S6.

Other key factors influencing the science and technology subjects studied in S5 or S6 were: average attainment at Standard Grade; whether the young person had studied the subject in S4, and attainment in the subject; the number of science or technology subjects studied and attained at Standard Grade; and attainment in mathematics at Standard Grade. Other factors were whether the young person had university aspirations and clear career intentions.

Why do young people opt out of science and technology in S5-S6?

Standard Grade subjects were a key factor influencing the choice of subjects to be studied in S5 and S6. Very few students took science and technology subjects in S5 or S6 if they had not previously studied the subject at Standard Grade.

Young people who studied more than one science or technology subject at Standard Grade were a great deal more likely to study these subjects at S5 and S6. It is likely that, by studying more than one science, these young people developed appropriate scientific skills to a greater extent than pupils who studied just one science or technology subject, and they developed more confidence in their ability to study these subjects in future. Consequently, if more pupils could be encouraged to study more than one science or technology subject at Standard Grade, more young people are likely to develop the confidence to study science and technology at the post-compulsory stages. This reinforces the importance of ensuring that the choices made for Standard Grade keep open the option of study in post-compulsory education.

The pool of young people in S5 who had achieved credit-level awards in science, technology and mathematics at Standard Grade is relatively large:

- 63% of students have one or more credit-level awards in science subjects, but just 54% studied any sciences in S5/S6;
- 33% of students have one or more credit-level awards in technology subjects, but just 26% studied any technology in S5/S6;
- 48% of students have credit-level awards in mathematics, and 49% studied mathematics in S5/S6.

Why do students with credit-level awards in science and technology choose not to continue these subjects in S5 and S6? Part of the explanation may lie in perceptions that physical science subjects are difficult (although the SQA aims to maintain the same level of difficulty across all subjects) and that they need mathematical skills. Certainly, it was the highest-attaining pupils and those with credit-level mathematics who were most likely to take physics and chemistry in S5 and S6. But another reason that science subjects are perceived to be relatively more difficult may be because they draw on different learning skills than other subjects rather than their absolute level of difficulty.

Nevertheless, young people's perceptions of the relative difficulty of subjects are an important issue for their subject choices. Since the over-riding aim of young people staying on to post-compulsory schooling is to achieve qualifications, less-confident students may decide to avoid difficult subjects in which they have more chance of failure. Decisions to opt for safe choices may be reinforced by schools for whom performance targets and league tables are defined in terms of overall levels of achievement. In future it is possible that implementation of national guidelines for the 5-14 stages may ensure that pupils have more opportunity to study science and technology at earlier stages of education, and thus raise young people's confidence in their ability to study science and technology.

A further explanation for young people's choices to opt out of science may lie in their negative images of science (Driver *et al.* 1996). National qualifications in science subjects focus on detailed scientific content that has to be memorised, and the subjects may appear abstracted from real life experience, and thus uninteresting and unattractive to young people. On the other hand, perceptions of technology subjects as a having low status may be off-putting to students who are aiming for higher education.

Advanced courses in SET at age 18-19

In spring 2001, when the SSLS cohort were surveyed at age 18-19, 44% of young people were in full-time education at college or university. Eleven percent of the cohort were studying advanced courses in SET. The vast majority of students (some 93%) said *"I am doing this course so that I can get a satisfying job in the future"* and *"because I am particularly interested in the subject(s)".*

There was a continuing influence of having taken science subjects at both the Standard Grade and Higher stages, for example, 24% of young people who studied two or more science subjects at Standard Grade went on to study SET in higher education compared with just 5% of those who studied one science at Standard Grade.

Focusing on members of the cohort in higher education, there were marked gender differences in participation in SET, with almost half of male higher education students studying SET compared with one-fifth of female students. Other factors influencing the study of SET in higher education were: level of course; Higher Grade passes in specific subjects; numbers of science and technology subjects studied in S3/4 and S5/6; overall Higher Grade attainment; family background.

Table 3: Advanced courses studied in spring 2001 by number of Higher Grade awards in science, mathematics and technology (% of students studying advanced courses)

	Higher Grade				All in HE
	Science		Maths	Technology	
	One	Two or more		One or more	
SET					
Biological science	2	13	7	2	5
Physical science	7	11	8	5	6
Mathematics and Informatics	10	12	13	24	11
Engineering technology	12	12	12	21	10
Other					
Medicine & dentistry	<1	6	3	1	2
Subjects allied to medicine	10	18	13	5	11
Agriculture & related subjects	1	3	2	1	2
Architecture, building & planning	4	2	3	6	3
Social studies	11	7	10	6	11
Business & administration	18	7	15	12	16
Mass communication & documentation	6	1	2	5	7
Language & related disciplines	6	4	5	1	4
Humanities	4	1	2	2	3
Creative arts	6	1	3	7	6
Education	4	1	2	2	3
Other	1	1	1	1	2
Sample size (=100%)	*628*	*714*	*1318*	*513*	*2258*

A third of all young people who had started a higher education course by 18-19 were studying SET (Table 3). What did science-qualified young people study? Half of those who had gained two or more Higher Grade awards in science subjects were studying SET, as were half of young people who had gained one or more awards in technology, and two-fifths of students with Higher Grade mathematics.

Medicine and dentistry, and subjects allied to medicine, were two subjects areas studied by a substantial proportion of science-qualified young people. One quarter of students with two or more awards in science were studying medicine and dentistry or subjects allied to medicine, and among females with two or more science passes the proportion was one-third.

Levels of participation in most other subject areas by young people qualified in science, mathematics and technology did not differ substantially from those of other higher education students. An exception was business and administration courses: the proportion taking this curricular area was lower among those with two or more science Higher grades than the average for higher education students as a whole.

A survey of the first destinations of graduates in 1999-00 (Scottish Executive, 2001b) found that 60% of first-degree graduates in mathematics and informatics and engineering technology entered permanent employment compared with one-third of graduates in biological and physical science. Over a third of graduates in biological and physical science went on to further full-time study, which is a substantially higher proportion than the average of all graduates.

Implications for policy and practice

The school curriculum

As part of the Science Strategy for Scotland, Learning and Teaching Scotland has been asked to prepare exemplar materials for teachers of science in primary and secondary school, and to advise how best to ensure that all school pupils have the opportunity to acquire the capacity to cope as citizens and decision makers with scientific issues. Designing curricula for technology and science to meet this need is challenging. At present every young person in Scotland studies at least one science subject to the end of compulsory schooling, and thus it appears that we are some way towards ensuring that all young people have some understanding of science. But is this enough to give future citizens a critical understanding of scientific issues? A recurrent theme of commentaries on science education is that science is taught as a body of facts together with a set of mechanical processes. The status of knowledge is rarely questioned or even opened up for discussion (Driver *et al.*, 1996). Science education needs to provide "knowledge about science" rather than scientific knowledge itself, and to develop the skills to engage critically with science, and to ask the right questions (Ryder, 2001).

Existing national qualifications in chemistry, physics and biology focus on detailed scientific content which may make these subjects appear relatively difficult, abstracted from real-life experience, and thus uninteresting and unattractive to young people. Existing courses appear to focus on providing preparation for study of science at university. However, in 2001, just 11% of the whole SSLS cohort studied SET in higher education. We need to ask whether the needs of the other 89% of young people were provided for by the courses currently on offer in schools.

A further issue is that, in schools, technology and science are separated - they occupy different modes of the curriculum, and technology is given lower priority than science. Science is a relatively high-status curricular area with a reputation for being difficult: this is borne out by the evidence that high-attaining pupils tend to study physics and chemistry. On the other hand, many of the technology subjects have inherited the relatively low status of practical subjects such as metal work and woodwork which tended in the past to be studied by low-attaining males. Technology courses at Standard Grade cover the full ability range, and provide pupils with understanding and skills which could complement those experienced in science courses. As with science education, so with technology education, the challenge will be to educate all young people to think critically and creatively about the 'made' environment, as well as to educate the technologists and engineers of the future. The ability to evaluate technology, its impact and effects, should have greater priority within the curriculum. .

Widening access to higher education

Participation in higher education is significantly higher in Scotland than in England, and recent policies have attempted to widen access to non-traditional students. However, these policies have created a more diverse intake of students in terms of levels of attainment and social-class background, with a substantial number taking courses at sub-degree level and particularly in subjects other than science and engineering.

Levels of attainment are the key factor determining entry to degree-level courses. In addition, this study confirms that there is continuing social inequality in entry. Young people from high social class backgrounds, and those from independent schools were more likely to enter degree courses than their peers who had the same overall attainment but who came from other social backgrounds and schools. Social inequality is very persistent.

Financial constraints are one aspect of this social inequality and are an important issue in relation to widening participation in higher education. Current student funding arrangements mean that students face a severe debt burden, and this provides a major obstacle for non-traditional students (Forsyth & Furlong, 2000). Problems of student finance are a further problem for participation in SET. Many students need to take part-time jobs to ease the financial burden of study in higher education, but this is more difficult for students in science and engineering courses which have longer contact hours than other courses.

Subject choice and careers guidance

The Science Strategy includes examination of issues of supply and demand for science-qualified young people, and careers advice at the post-school stages. While this is welcome, there is an urgent need for enhanced careers guidance at the primary and early secondary stages of schooling. This report has chronicled the cumulative effect of subject choices at school on participation in SET in higher education. The crucial choices are made at the age of 13-14 when youngsters make their choice of Standard Grade subjects, and at 15-16 when they choose their Higher Still courses. If young people gain more science qualifications at school they are more likely to participate in SET in higher education. Young people need to be more aware that studying science and technology can open up a range of career opportunities, and provide worthwhile skills. Qualifications in technology and science are useful in a wide range of careers. At this early stage, youngsters rarely have clear ideas about future careers and need more careers advice and support with decision-making at earlier stages of their education.

Research into the supply and demand for SET graduates will provide the basis for more informed decision-making by prospective entrants to higher education. The overwhelming majority of undergraduates were seeking a satisfying job to follow from the subject courses they were studying.

However, at the end of their courses most faced the prospect of large student debts, and uncertain job prospects. Better information and careers advice may go some way to making their careers search easier. Perceptions of well-paid careers in computing and information technology have undoubtedly been part of the reason for the growth in entry to these areas of SET. However, the career prospects for graduates from other aspects of SET are much less clear. The problems graduates experience in securing careers in their chosen fields are difficult and demoralising for the individuals, and will provide negative feedback to future higher education applicants.

At present it is not clear whether Scotland really needs more SET graduates. The analysis of supply and demand carried out as part of the Science Strategy may clarify the position. If there is a need for more graduates in specific areas of SET, we need to ensure that SET courses provide the full range of relevant and transferable skills to enhance the employability of graduates.

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About the CES Special Briefing: Participation in Science, Engineering and Technology

The findings reported here are based on secondary analysis of data from the Scottish School Leavers' Survey (SSLS). It focuses on the cohort of young people who completed the S4 stage of secondary schooling in session 1997/8 who were surveyed in spring 1999 and spring 2001. Information about subjects studied at school has been derived from linked data supplied by the Scottish Qualifications Authority.

Non-response bias at each sweep has been corrected using weighting factors based on sex and qualifications. Percentages shown in the tables are based on weighted data, while all sample sizes are reported unweighted. Unweighted sample numbers show the actual sample size on which the percentage estimate is based and thus give a more realistic idea of the reliability of each estimate. Percentages shown in the report are rounded to the nearest whole number; this means that some columns may not sum to 100%.

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A limited number of additional copies of this CES Special Briefing may be obtained by writing to Carolyn Newton, Centre for Educational Sociology, University of Edinburgh, St John's Land, Holyrood Road, Edinburgh EH8 8AQ. It is also available for download from the CES website (www.ed.ac.uk/ces).

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