

House of Commons
Science and Technology
Committee

**SCIENCE EDUCATION
FROM 14 TO 19**

Third Report of Session 2001–02

Volume I

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Footnotes

In the footnotes of this Report, references to oral evidence are indicated by 'Q' followed by the question number. References to written evidence are indicated by the page number as in 'Ev 12'. The evidence is published in a separate volume (HC 508-II).

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SUMMARY

Science education is a matter of crucial importance to the UK, both for the future generations of scientists, engineers and technologists and for the wider public. Science and technology are essential for our economic competitiveness, and to our quality of life, and lie at the heart of our history and culture.

Science has been a core part of the education of all students up to the age of 16 since the introduction of the National Curriculum in 1989. Most students take double science GCSE from 14 to 16. This course aims to provide a general science education for all and, at the same time, to inspire and prepare some for science post-16. It does neither of these well. It may not be possible for a single course to fulfil both these needs. Government is supporting a pilot that may resolve these tensions, which is welcome but not enough. Existing GCSE courses should be changed and a wider range of options in science offered to students.

Current GCSE courses are overloaded with factual content, contain little contemporary science and have stultifying assessment arrangements. Coursework is boring and pointless. Teachers and students are frustrated by the lack of flexibility. Students lose any enthusiasm that they once had for science. Those who choose to continue with science post-16 often do so in spite of their experiences of GCSE rather than because of them. Primary responsibility should lie with the awarding bodies; the approach to assessment at GCSE discourages good science from being taught in schools.

Government has said that it will revise the science National Curriculum for 14 to 16 year olds. This is welcome, but it will have no effect unless the approach to assessment at GCSE is revised too. A new National Curriculum should require all students to be taught the skills of scientific literacy and selected key ideas across the sciences. This core should form the basis of a wider and more flexible range of exam courses, reflecting the diverse interests and motivations of students

Teachers are the key to developing and delivering a vibrant science curriculum. They must be consulted on any changes to the National Curriculum and assessment. They will need time, resources and training if they are to be able to implement change.

At AS and A level, innovative new courses have been developed. These have the potential to engage and interest students. We look to universities to respond positively to these developments. To encourage more students to continue with science post-16, there needs to be a wider range of courses available and students need better information about the value of science to their future careers.

Practical work is a fundamental part of science education. Health and safety regulations do not constrain practical work: inadequate and overcrowded laboratories, a shortage of technical support and an over-prescriptive curriculum do. DfES has provided £60 million to refurbish school science labs; a significant sum but not sufficient. At least a further £120 million is needed if all schools are to have adequate science accommodation.

Technicians have a vital role to play in providing high quality science education. Schools need to employ an additional 4,000 technicians if science departments are to be properly supported. It will only be possible to recruit these additional staff if the appalling pay and conditions for technicians are improved.

THIRD REPORT

The Science and Technology Committee has agreed to the following Report:

SCIENCE EDUCATION FROM 14 TO 19

INTRODUCTION

1. School science education has long attracted considerable interest. The Devonshire Royal Commission published a report in 1875 which said that “still no adequate effort has been made to correct the deficiency of scientific instruction pointed out by the commissioners in 1861 and 1864. We were compelled therefore, to record our opinion that the present state of scientific instruction in our schools is extremely unsatisfactory”. This Committee in previous Parliaments raised issues relating to science education in several reports.¹ The Education Committee published a report on science education from 7 to 14 in 1995. In 2001, the House of Lords Science and Technology Committee reported on continuing professional development for science teachers.² The Council for Science and Technology considered continuing professional development in their report on science teachers, published in 2000, and reported on the relationship between the sciences and the arts in 2001.³

2. Science education is a matter of crucial importance to the UK, both for the future generations of scientists, engineers and technologists and for the wider public. Science and technology are essential for our economic competitiveness, and to our quality of life and lie at the heart of our history and culture. We need people qualified in science and engineering at all levels and all areas of the economy. We decided that our first major inquiry of the Parliament should be into science education in schools. Our intention was to influence the review of science education which is to be undertaken following the recent Government Green Paper 14-19 and to complement the Review led by Sir Gareth Roberts on the contribution of school science to ensuring a supply of scientists and engineers.⁴ Our inquiry relates to England, though our findings may have relevance to other parts of the UK.⁵

3. Our terms of reference specifically excluded the issue of teacher supply, on the ground that this requires an inquiry of its own and could not be limited to the shortage of science teachers. The supply of science teachers is a crucial issue and has been raised with us repeatedly, and is a particular concern for physics and chemistry where there are severe shortages of subject specialists. The developments in curriculum and assessment discussed in this report will have no effect unless a strong and confident teaching force is maintained.

4. We began our inquiry by holding an informal seminar in January with Professor Edgar Jenkins, formerly of Leeds University, Professor Robin Millar of York University and our specialist advisers. We had an informal meeting in February with Sir Gareth Roberts. We

¹ Most recently, Sixth Report, Session 2000-2001, Are we realising our potential?, HC200-I, paragraphs 57-60.

² Education Committee, Fourth Report, Session 1994-95, Science and technology in schools, HC28-I. House of Lords Science and Technology Committee, First Report, Session 2000-2001, Science in Schools, HL49.

³ Science Teachers: a report on supporting and developing the profession of science teaching in primary and secondary schools, February 2000. Imagination and Understanding: a report on the arts and humanities in relation to science and technology, July 2001. Both reports are available via www.cst.gov.uk

⁴ Green Paper 14-19: extending opportunities, raising standards was published by DfES in February 2002. Chapter 3 refers to science. It can be seen at www.dfes.gov.uk/14-19greenpaper. The Report of Sir Gareth Roberts' Review into the supply of scientists and engineers was published in April 2002. Chapters 2 and 3 refer to schools. Available via www.hm-treasury.gov.uk

⁵ Responsibility for education in Scotland, Wales and Northern Ireland is devolved to the Scottish Parliament, the National Assembly for Wales and the Northern Ireland Assembly.

issued a call for evidence and have received 107 items of written evidence from individuals and organisations. We held five oral evidence sessions with: scientific and engineering learned societies; AS and A level students, held at the Science Museum in London; practising teachers, Further Education lecturers and technicians; employers, universities and witnesses interested in science for citizens; and the Qualifications and Curriculum Authority and the awarding bodies, and Stephen Timms MP, the then Schools Minister at the Department for Education and Skills.⁶ The Committee visited Quintin Kynaston School, St John's Wood, London and Westminster School, London to speak informally with teachers, technicians and students. A further informal meeting was held at Westminster with staff and students from Hammersmith and West London Further Education college. To compare the system in England with that in Scotland, the Committee visited Beeslack High School, Penicuik, near Edinburgh. We were briefed there by Jack Jackson HMI on science education in Scotland and discussed the issues further with four other science education experts. We also met with teachers, students and technicians. Individual members of the Committee made informal visits to schools and colleges in their constituency areas: Fareham, Norwich, Trowbridge, Bolton, Somerset and Castle Point in Essex. Details of these visits are printed in Annex 1.⁷

5. We are grateful to all those who have assisted with the inquiry, and in particular to our Specialist Advisers: Professor Michael Elves, former Director of the Office of Scientific and Educational Affairs, Glaxo Wellcome plc; Professor Jonathan Osborne of King's College, London; and Ms Becky Parker, former Head of Science at Simon Langton Girls' School, Canterbury. Our thanks are also due to the Parliamentary Office of Science and Technology on which we have relied heavily for staff support in this inquiry.

6. The young people from whom we took formal evidence were drawn from the steering group of a student review of the National Curriculum. This review was based on an on-line survey of people's views of GCSE science. The survey was carried out between October 2001 and March 2002 under the coordination of the Science Museum. 2,000 young people from across the country responded. We ourselves conducted a small survey of the views of young postgraduate and postdoctoral scientists, brought together by the Royal Society of Chemistry in March 2002, on their experiences of science education at school.

7. We are grateful to the Foreign and Commonwealth Office Science and Technology Unit for providing us with information about science education in a number of countries overseas. Details are given in Annex 2.⁸ We have also received useful information from UNESCO, which has been active in promoting good practice in science and technology education around the world, and from the Spanish Senate where the Education, Culture and Sport Committee is conducting an inquiry into science education in secondary schools, motivated by concerns which are very similar to our own.⁹

8. In this report we set out the findings of our inquiry. We explain the existing arrangements for science education from 14 to 19, identify problems which currently exist at 14 to 16 and post-16 including the resources for practical science, and propose a number of ways forward. Our intention is that this report will draw political attention to science education, inform the House and influence Ministers in developing Government policy and allocating expenditure.

⁶ The transcripts of the oral evidence, and written evidence, are published in Volume II to this Report

⁷ See p 65

⁸ See p 70

⁹ For details of UNESCO's science and technology education programme see www.unesco.org/education.stc
Details of the Spanish Senate's inquiry can be found via www.senado.es

BACKGROUND

Science in the National Curriculum

9. The National Curriculum was introduced in 1989 and, for the first time, specified the minimum that all pupils in English state schools should be taught during their years of compulsory education. Science, English and maths, became core subjects which were mandatory for all pupils from ages 5-16. The National Curriculum covers not only the three core subjects but also design and technology, information and communication technology (ICT), a modern foreign language, geography, history, art, music, physical education and citizenship. The Qualifications and Curriculum Authority (QCA), a non-departmental public body accountable to the Department for Education and Skills (DfES), is responsible for developing and monitoring the National Curriculum for England.¹⁰ The National Curriculum was most recently revised in 1999 for implementation in 2000.¹¹ It is divided into four age bands or “key stages”. This inquiry focuses on the last of these which covers ages 14-16 – “key stage 4”.

10. 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 National Curriculum for Science is presented in four sections. These are outlined in figure 1 below, with examples drawn from key stage 4.

Figure 1: Outline of the National Curriculum for Science

Scientific Inquiry (Sc1), which encompasses teaching about scientific ideas and evidence including consideration of scientific controversies and ethical issues; and the development of investigative skills, which includes planning experiments, carrying them out, drawing conclusions and evaluating the results.

Life Processes and Living Things (Sc2), which includes aspects of biology such as cell structure and function, photosynthesis and genetics.

Materials and their properties (Sc3), which covers aspects of chemistry such as atomic structure, chemical reactions and the periodic table; together with aspects of earth science such as rock formation.

Physical processes (Sc4), which includes aspects of physics such as electricity, forces and waves; together with aspects of astronomy such as the evolution of stars.

11. Independent schools do not have to follow the National Curriculum, which means that they can give their pupils the option to choose between individual science subjects at GCSE rather than having to maintain a balance (see section (b) in paragraph 13 below). However, as all science GCSE courses are based on the National Curriculum, independent schools are, in effect, teaching the National Curriculum at 14 to 16.

¹⁰ QCA was established by the 1997 Education Act as a merger between the School Curriculum Assessment Authority and the National Council for Vocational Qualifications.

¹¹ The National Curriculum is available at www.nc.uk.net

Science at GCSE

12. During the two years of key stage 4 most pupils work towards GCSEs (General Certificate of Secondary Education). QCA specifies that GCSE courses must fulfil the requirements of the National Curriculum; defines the proportions of the assessment that should be based, for example, on factual recall or application of knowledge; lays out what percentage of the final marks should be based on coursework; and describes what, for example, a Grade A candidate would be expected to demonstrate. It is then up to the three awarding bodies (AQA, Edexcel and OCR) to put this into practice through their specifications (previously known as syllabuses) and exams. Every specification must be approved by QCA. These go into considerably more detail about what students should be taught than the National Curriculum. For example, the “life processes and living things” component of one AQA GCSE specification fills 22 pages, compared to three pages in the National Curriculum.¹² The awarding bodies must submit to QCA specimens of the types of question that they intend to ask in their exams, although actual exam papers are not approved in advance. The GCSE specifications have all been recently revised and these new courses will be examined for the first time in summer 2003.

13. To fulfil the requirements of the National Curriculum, pupils in state schools must study GCSE science courses that provide a balance across biology, chemistry and physics. There are three ways of doing this. All of the options are intended to be of the same level of difficulty but differ in the breadth of content that is covered.

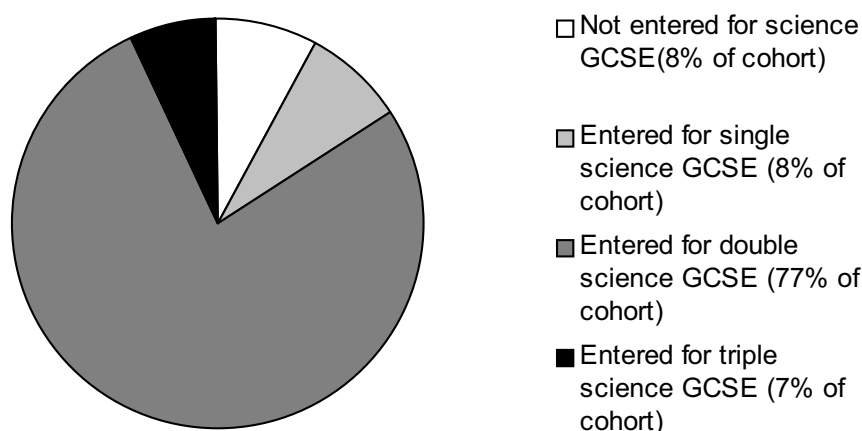
- (a) *Double science* GCSE is the norm, entered by 77% of the cohort in 2001.¹³ The content of the course is balanced across the sciences and is equivalent in content to studying two GCSEs. Pupils would normally need to spend 20% of their school time studying science to cover the content of this course. They are awarded two identical GCSE grades that reflect achievement across the sciences.
- (b) *Separate biology, chemistry and physics* GCSEs can be studied; this is sometimes called *triple science*. QCA specify that each of these GCSEs should contain 25% more subject content than the related component in double award GCSE. In 2001 each of the separate sciences were entered by 6-7% of the cohort. Some of these students will have been in the independent sector and may not have taken all three of the sciences.
- (c) *Single science* GCSE keeps the balance across the scientific disciplines but with approximately half the content of double science. It was entered by 8% of the cohort in 2001 and students are awarded one GCSE. This option was intended for a minority of students who have a particular reason to spend time on other subjects (gifted linguists, for example). In practice, the low pass rate (only 12% of entrants passed with grade A*-C in 2001, compared to 52% for double science) suggests either that the course is taken mainly by lower ability students or that it is more difficult than the other GCSE science courses.

The National Curriculum states that “The Government firmly believes that double science or the three separate sciences should be taken by the great majority of pupils”. Figure 2 shows that this is the case.

¹² AQA specification for Science: Double Award (Coordinated)

¹³ A total of 576,700 students entered GCSEs in 2001. *Source:* GCSE/GNVQ and A/AS/VCE/AGNVQ examination results 2000/01 (early statistics). DfES. October 2001. Table 4. Available via www.dfes.gov.uk/statistics

Figure 2: The proportion of the GCSE cohort entering single, double, triple or no science GCSEs.



14. In 2001, 8% of the cohort did not enter any GCSE science. This is similar to the figures for English and maths GCSEs, which saw no entries from 8% and 7% of the cohort respectively. There are a number of possible explanations for this. In 2001, 0.21% of the cohort were officially disapplied from the science requirements of the National Curriculum by their schools. This was so that they could instead spend time on work related learning and would have meant that they did not study any science at all.¹⁴ It is worth noting that the Green Paper 14-19 proposes that the facility to disapply science at key stage 4 should be removed. Other students will have been entered for entry level certificates, designed for those pupils who would be unlikely to achieve a grade G at GCSE; or have been entered for a science General National Vocational Qualification (GNVQ).

15. The awarding bodies offer several different specifications within each of the three possible structures for science GCSE. Schools are free to choose which of these they want to use. For example, for double science GCSE, AQA offer both a modular and a co-ordinated specification. The main feature of the modular course is that 30% of the marks are based on six tests taken at fixed points throughout the two year course; the co-ordinated qualification is examined only at the end of the course. In 2001, 44% of double science GCSE entries were for modular specifications.¹⁵ In both of these approaches the traditional boundaries between biology, physics and chemistry are largely maintained. In contrast the Salters specification, one of the those offered by OCR, takes a topic-based approach where science is taught through familiar contexts and applications.¹⁶ For example, the topic Food for Thought includes teaching about plant nutrients (biology) and the manufacture of fertilisers (chemistry). In 2001, candidates for the Salters specification accounted for 10% of the entries to double science GCSE.

16. For the new GCSEs that will be examined from 2003, QCA specifies that 20-30% of the marks in any science GCSE must be assessed through coursework. The 20%

¹⁴ Figure provided by QCA and based on information provided by schools. The actual figure may be higher. Since 1998, schools have been able to disapply individual students from science at key stage 4 so that they are able to take part in work related learning. Disapplication from design and technology and modern foreign languages is also permitted, although for a wider range of reasons. In 2001, 2.2% and 4.3% of the cohort were disapplied from design and technology and modern foreign languages respectively. The DfES Green Paper 14-19 proposes that, at key stage 4, design and technology and modern foreign languages should become optional for all.

¹⁵ Figures provided by AQA based on entries across all awarding bodies.

¹⁶ The development of the course was funded by the Salters' Company.

minimum must be based on assessment of pupils' investigative skills as defined in figure 3. On the basis of these criteria, the awarding bodies have agreed a structured mark scheme which is common across all GCSE science courses and is worth the minimum 20%. The shared mark scheme is intended to ensure that standards are comparable across the awarding bodies.

Figure 3: Investigative skills: extract from QCA's specification for GCSE science

Candidates must be able to:

- (a) Devise and plan investigations, drawing on scientific knowledge and understanding in selecting appropriate strategies;
- (b) Demonstrate appropriate investigative methods, including safe and skilful practical techniques, obtaining data which are sufficient and of appropriate precision, recording these methodically;
- (c) Interpret data to draw conclusions which are consistent with the evidence, using scientific knowledge and understanding, whenever possible, in explaining their findings;
- (d) Evaluate data and methods.¹⁷

Proposed developments at GCSE

17. QCA will be piloting a new approach to GCSE science from September 2003 in volunteer schools.¹⁸ In this pilot, which has a working title of "Science for the 21st Century", all students will take a common single core science GCSE. This will incorporate the key concepts from across the sciences (for example, chemical change, biodiversity, energy sources) but give equal emphasis to scientific literacy and students' abilities to use skills such as interpreting data, understanding risk and appreciating the impact of science on society. Students will then take extra modules leading to a second or third GCSE either of an academic nature, which would be expected to prepare them for AS and A level science, or of an applied/vocational nature, which would allow them to move on through vocational routes such as the Advanced Vocational Certificate of Education (VCE).

Science at AS and A level

18. Since September 2000 a new structure for AS (Advanced Subsidiary) and A (Advanced) levels has been introduced which aims to broaden the range of subjects studied by students post-16. It was envisaged that students would choose to study 4-5 subjects in their first year post-16, leading to the award of an AS level qualification in each. They might then choose to continue with three of these subjects for the second year, known as A2, and leading to the award of a full A level.

19. The traditional science subjects of biology, physics and chemistry are offered by all three of the awarding bodies at AS and A level.¹⁹ Some 50-60% of the content of each specification is defined by QCA and therefore common across all the awarding bodies.²⁰ The flexibility over the remaining content has led both to the development of courses where

¹⁷ Extract from QCA's GCSE criteria for science. Available at www.qca.org.uk/nq/framework/science.pdf

¹⁸ Ev 115, para 7

¹⁹ Biology includes human biology. Other AS and A level subjects that incorporate significant amounts of science are environmental science, geology, physical education, and psychology. See also Ev 136, Appendix 22 and Ev 140, Appendix 24 for proposed new subject areas.

²⁰ QCA's criteria for AS and A levels can be seen at www.qca.org.uk/nq/framework/main.asp

schools are able to select topics within specifications and to the development of several innovative courses. These include: Salters Advanced Chemistry developed by the University of York with sponsorship from the Salters' Company; the Advancing Physics course developed by the Institute of Physics; Salters Horners Physics developed by the University of York with sponsorship from the Salters' and Horners' Companies; and the Salters-Nuffield Advanced Biology which is under development at the moment. The first two of these specifications are offered by OCR and the latter two by Edexcel.

20. A further interesting development is the introduction of an AS level in Science for Public Understanding, developed by the Nuffield Foundation and offered by AQA. This course aims to give students the opportunity to reflect on scientific issues in a wider context than in a specialist science course. Students are expected to gain a knowledge of selected topics drawn from across the sciences. These are studied in either historical or topical contexts. The course has attracted some 770 entries this year, over half from girls.

Vocational qualifications

21. Some students choose to follow vocational courses, which are more closely linked with the world of work, instead of the traditional GCSE or A levels courses. These are appropriate for students who prefer learning through work-based contexts and being assessed mainly through coursework rather than exams. The vocational courses most likely to be followed by 14-19 year olds are the General National Vocational Qualifications (GNVQs), which are linked to broad vocational areas including Science, Health and Social Care and Engineering. Each GNVQ can be taken at three different levels: foundation, intermediate and advanced. Advanced GNVQs, which have recently been renamed and launched as Advanced Vocational Certificates of Education (VCE), are equivalent in standard to traditional A levels. Intermediate GNVQs are equivalent to GCSE grades A*-C and Foundation to GCSE grades D-G. GNVQ courses are most commonly taken post-16 with intermediate level appropriate for those who have not achieved grade C in science at GCSE and advanced as an alternative to A level. DfES also permits schools to offer foundation and intermediate GNVQ science at key stage 4 even though the courses do not fulfil the National Curriculum criteria.²¹ This option has not been widely taken up by schools or students. Statistics on the number of students entering Advanced GNVQs are presented in figure A9, Annex 3.²² Numbers for intermediate and foundation GNVQs are lower.

22. From September 2002 a new GCSE in Applied Science will be offered by all three awarding bodies. It is intended to replace the Intermediate and Foundation GNVQs in science, which QCA has said will be examined for the last time in 2006. This new GCSE is designed to appeal to those students who do not enjoy traditional academic study and aims to prepare them to move on to further vocational courses or employment. The course is expected to take the same amount of time to teach as the double award science GCSE and two thirds of the assessment will be based on coursework, reflecting the emphasis on the development of technical skills. It is expected that the course will attract considerably more entries than the GNVQs.

²¹ This is permitted under the provisions of Section 96 of the Learning and Skills Act 2000. Further information is available from www.dfes.gov.uk/section96

²² See p 87

International comparisons

23. Students in England have taken part in two recent studies that aim to compare the performance of young people in science across countries. The Third International Maths and Science Study (TIMSS), carried out in 1999, assessed the performance of 13 and 14 year olds across 38 countries.²³ In science, England was placed ninth. Although this ranking was higher than the previous TIMSS, carried out in 1995, the actual performance was broadly the same. A further TIMSS study will be carried out in 2003. The Programme for International Students Assessment (PISA) was carried out by the OECD in 2000 and involved 32 countries.²⁴ On the assessment of 15 year olds' scientific literacy, England was ranked fourth.

²³ For further information see isc.bc.edu/timss1999.html

²⁴ www.pisa.oecd.org

SCIENCE AT 14 TO 16

24. The vast majority of evidence that we received in our inquiry related to science for 14-16 year olds. **It is clear that the major problems lie at key stage 4.** Though we have met some inspirational teachers and some inspired students it is clear that the curriculum and assessment at key stage 4 is preventing school science from being exciting. The curriculum is said to be inflexible, irrelevant, repetitive and prevents debate. The limited range of courses available fail to meet individual needs. The practical work required for these courses is frequently uninteresting and demotivating. The potential for the imaginative use of ICT is not exploited. As a result, **many students lose any feelings of enthusiasm that they once had for science. All too often they study science because they have to but neither enjoy nor engage with the subject. And they develop a negative image of science which may last for life.**

Inflexibility

25. Michelle Ryan, a teacher at Ricards Lodge High School, Wimbledon told us “in schools, as a head of department, the most important thing to us is exam results. Success is a very, very powerful driving force”.²⁵ The effect of this is that teachers dedicate class time to teaching only that material which is directly required for the GCSE. Lexi Boyce, a student at Long Road Sixth Form College, Cambridge, told us “to be able to pass exams, which is what you are doing, you only have time to cover the facts and learn them”.²⁶ When we visited Westminster School, one student commented that being good at science just showed that you were good at memorising facts. This leaves little time to follow up or explore areas of interest to students, or indeed of interest to teachers. Because of this teachers and pupils alike feel that the curriculum is overloaded. TIMSS quantified the amount of emphasis that teachers in different countries place on scientific reasoning and problem solving. In England it was less than half that of the international average.²⁷ We suggest that this is a reflection of the assessment demands, which give too much emphasis to low level intellectual skills such as recall.²⁸ Derek Bell, from the Association for Science Education, said that the key issue affecting science education “is about giving teachers the space and time to teach as they would wish to teach in terms of getting students involved and motivated”.²⁹ This is reflected in comments that we have heard from students. Lucy Ferguson, a student at Guildford High School who had chosen not to study science at A level, said of her experiences at GCSE that “I would have liked greater flexibility so I could do stuff I enjoyed, stuff that actually interested me”.³⁰ **The GCSE science curriculum is over-prescriptive. This puts students off science because they do not have the flexibility to explore areas which interest them. It kills the interest in science which may have been kindled at primary school.**

Irrelevance

26. In the online survey of young people’s attitudes to GCSE science hosted by the Science Museum, 67% of respondents said that GCSE science should be based primarily on real life, relevant issues. Students at Portchester Community School in Hampshire

²⁵ Q231. See also Ev 89, para 12

²⁶ Q189

²⁷ TIMSS 1999 International Science Report, Chapter 6, figure 6.12. Available via isc.bc.edu/timss1999.html

²⁸ Ev 108, para 5; Ev112, para 3; Ev 134. See also comments relating to maths Ev 138, paras 2.2-2.3

²⁹ Q343

³⁰ Q211

thought they studied science because “it gives us an explanation of events in everyday life”.³¹ Teachers at St Augustine’s Catholic College, Trowbridge suggested that their notable success at attracting students to continue with science was because they made particular effort to make science relevant.³² Relevance is something that can be brought to the curriculum by teaching science using examples and contexts that the students can relate to. For example, Vicky Parkin, a student at Queen Elizabeth Sixth Form College, Darlington suggested that the manufacture of ammonia in the Haber process should be taken out of the GCSE curriculum because it was not relevant to those studying general science.³³ When we proposed this to a teacher at Quintin Kynaston School he pointed out that the Haber process had been developed to facilitate the manufacture of explosives in World War I: through bringing this history into his science teaching he felt that it was possible to make the topic interesting and relevant for his students.

27. One way of ensuring relevance to students is to teach contemporary science. Some aspects of modern science have made it into the National Curriculum. For example, at key stage 4, the National Curriculum requires students to be taught “the basic principles of cloning, selective breeding and genetic engineering”.³⁴ But most science taught at ages 14 to 16 has remained largely unchanged for decades. David Moore of the Association for Science Education, told us that “We need to provide opportunities where [students] can discuss what is going on in today’s science rather than the science of 50 or 100 years ago”.³⁵ Hannah Greensmith, a student at Birkenhead High School, Wirral told us that “we should learn more about what is going on in the world around us and up-to-date issues like the foot and mouth crisis..., which we hear about every day”.³⁶ **If students are to be able to see the relevance of their school science, the curriculum should include recent scientific developments.**

Failure to engage in debate

28. The Science Museum’s on-line survey of attitudes to GCSE science found, not only that young people wanted to be taught more relevant and contemporary science, but also that 69% wanted this to include controversial issues. This might mean discussing the health effects of using mobile phones, the disposal of nuclear waste or the investment of public money in exploring Mars. In the same survey, 48% of the respondents reported that they found discussion and debate in class to be the most useful way of learning, more than for any other classroom activity. However, research conducted by Ralph Levinson of the Institute of Education for the Wellcome Trust has shown that many science teachers feel that they lack not only the time to tackle the discussion of controversial issues in class, but also the confidence to use this type of teaching style.³⁷ In addition, almost half of the science teachers that were interviewed by Ralph Levinson felt that science teaching should be “value free”. In contrast, their humanities and English teaching colleagues actively promoted discussions on ethical and social issues with their classes. As Jerry Ravetz puts it, “science education is one of the last surviving authoritarian social-intellectual systems in Europe”.³⁸ The Head of Biology at St Augustine’s Catholic College, Trowbridge said that she was concerned that where the curriculum did include areas of controversy, they were tended to be presented as facts. She cited the greenhouse effect, where there is

³¹ Ev 198

³² Ev 203, item 3

³³ Q169

³⁴ Extract from the National Curriculum for science. Available via www.nc.uk.net

³⁵ Q337. See also Ev 173, para 15

³⁶ Q94

³⁷ Ev 107, Appendix 9, para 2. Valuable Lessons: Engaging with the social context of science in schools. 2001. Available via www.wellcome.ac.uk. See also Ev 159, paras 15-17

³⁸ Ev 109, Appendix 10

considered to be a “right answer for the purposes of the exam paper”.³⁹ **Students want the opportunity to discuss controversial and ethical issues in their science lessons, but this happens very rarely.**⁴⁰ **Engaging in debate is an approach to teaching that is unfamiliar to many traditional science teachers; and the way that science is assessed means that students are not rewarded for thinking for themselves or for contributing their own ideas.**

Repetitiveness

29. Students have complained to us that the GCSE courses feel repetitive, going over much of the ground that they covered in earlier years. Ed Walsh, a teacher at Roseland Community School, Truro told us that “An awful lot of what we teach at the moment is bread-and-butter stuff and some of it is fairly repetitive”.⁴¹ Teachers from schools in Bolton expressed particular concern about the “spiral” nature of the curriculum where topics are revisited in different key stages.⁴² On each occasion the topic is intended to be covered in more depth, but students may experience this as repetition.⁴³ Martin Hollins of QCA told us that, from their own monitoring of GCSE science, “that there is a quite a lot of repetition in the teaching, to make sure that students have got something”.⁴⁴ It seems that this repetition is being driven by the examination system with teachers going over old material so that they can feel confident that their students are fully prepared for assessment. Martin Hollins told us that, in revising the National Curriculum, QCA “made more of a distinction between what is appropriate at a particular age group”.⁴⁵ The effects of these changes will not become apparent until the new key stage 4 National Curriculum is first assessed in 2003. **During GCSE students repeat much of the science that they have covered in key stage 3. Inevitably they find this boring.**

Limited options

30. Mike Collins, a teacher at Hengrove School, Bristol told us “For post-14 I do not think there is a clear view about why we are making students study science. I think we should but I do not think the answer is the same for all students”.⁴⁶ Sylvia Thomas, a teacher at Darlaston Community School, Walsall agreed: “I think one size does not fit all, that is absolutely obvious, ... we need diversity”.⁴⁷ Mike Collins wants to see “a greater range of science courses post-14 designed for different purposes: preparation for further more advanced study; learning science in the context of vocational areas which use scientific skills; a more general ‘science for citizenship’ course”.⁴⁸ We are told that the current “science curriculum [is] broadly similar to that formerly offered to students in academic streams as a preparation for more advanced study”.⁴⁹ However, at the same time it is intended to be a curriculum appropriate for all students to study, regardless of their interest or ability in science.

³⁹ Ev 203, item 4

⁴⁰ Newton, P., Driver, R., & Osborne, J. (1999). The Place of Argumentation in the Pedagogy of School Science. *International Journal of Science Education*, 21(5), 553-576. This research found that deliberative discussion between pupils, or between pupils and teachers, of science or its applications occupied less than 5% of classroom time.

⁴¹ Q267

⁴² Ev 200

⁴³ Q265

⁴⁴ Q454

⁴⁵ *Ibid.*

⁴⁶ Q265

⁴⁷ Q271

⁴⁸ SED65 Unprinted evidence. See also Ev 92, para 2.3

⁴⁹ Ev 155, para 5

31. The main options available at 14-16 are single, double and triple GCSE. All of these courses take a very similar approach to science. Most students take the double award, while schools may offer the triple award to more able students and single award to less able. The single award was not intended to be for less able students. It is interesting to compare the responses of the three groups of students to the Science Museum's on-line survey. For example, some 12% of triple award students reported struggling with maths within science, rising to 20% for double and almost 40% for single award students. And over 50% of triple award students thought that their science GCSEs had not gone into enough depth, while over 20% of single award entrants – more than double that of triple award – said that they did not care. This suggests that single award students are less engaged and interested by their GCSE science course than triple award students and that the triple award course is insufficiently demanding of the students who do it.

32. Teachers at St Augustine's Catholic College in Trowbridge said that current arrangements particularly let down less able students, forcing them to do work with which they struggle.⁵⁰ Ofsted tell us that the single science GCSE “is poorly matched to the needs and interests of those [lower attaining students] who take it”.⁵¹ It was suggested at St Augustine's that a more practically based curriculum might be more acceptable for less academically gifted students. By comparison, in the Science Museum's survey, the single award students reported doing less practical work than others, with triple award doing the most. At the same time it seems that higher attaining students are not well provided for. Mike Collins from Hengrove School, Bristol told us that GCSE science “is recognisably academic preparation for further advanced study [but] what they get is a watered down version of it, which is not very motivating”.⁵² The Nuffield Foundation fear that “the reduction in challenge for the more able...is making many of them bored with science”.⁵³ This view is reiterated by the scientific learned societies when they say that “the current curriculum...fails to inspire and challenge many who have the ability to continue with science-based studies”.⁵⁴ **The science curriculum at 14 to 16 aims to engage all students with science as a preparation for life. At the same time it aims to inspire and prepare some pupils to continue with science post-16. In practice it does neither of these well.**

33. Vocational qualifications should provide an alternative but few schools have chosen to offer foundation and intermediate GNVQ science at key stage 4 instead of GCSE. The GCSE in Applied Science, described in paragraph 22 above, may be more popular when it becomes available in September 2002. This is an attempt by Government to raise the status and take-up of vocational qualifications by aligning them more closely with traditional courses. Several teachers have told us that they see this new GCSE as a step in the right direction in providing a range of courses to suit different students.⁵⁵ This may be true for students that are more motivated by the different styles of learning and assessment associated with vocational qualifications. But the Association of Colleges are concerned that this new course may be too closely aligned with existing GCSEs to offer something genuinely different. In particular, they say that it “offers nothing for those with lower achievements”.⁵⁶ This is difficult to judge because the Applied Science GCSE has not been piloted. The Deputy Head at St Augustine's Catholic College in Trowbridge said that he thought that plans for this new GCSE were not yet mature and needed testing before being unleashed.⁵⁷

⁵⁰ Ev 202, para 2

⁵¹ Ev 135

⁵² Q265

⁵³ Ev 155, para 6

⁵⁴ Ev 83, para 2

⁵⁵ Ev 200; Ev 202, item 2

⁵⁶ Ev 103, para 121

⁵⁷ Ev 204, item 7

Problems with practical and field work

34. Practical work forms a significant part of science education in England. Indeed, the TIMSS survey of 14 year olds in 1999 reported that it is only students in Hong Kong and Thailand that spend more time on conducting experiments than students in England.⁵⁸ Students themselves will carry out a range of practical work including dissection; one-off experiments, where they follow a set of instructions that allow them to observe a particular scientific principle; and longer pieces of investigative work, where students aim to explore an aspect of science in more depth. A full investigation would involve students planning their own experiment, carrying it out, analysing the results, drawing conclusions and evaluating how successful their investigation was. The hands-on ‘carrying it out’ stage involves laboratory practical work. At GCSE, students are required to demonstrate their skills at every stage of an investigation through coursework. Practical work may also mean demonstration of experiments by teachers to their students instead of by students themselves. This is normally to prevent a health and safety risk to students, but may also be because of a shortage of equipment, consumables or time.

35. Fieldwork can be broadly defined as practical work that happens outside the laboratory. Teachers are most likely to make use of the external environment when teaching ecology or earth science. Some schools will be able to carry out interesting fieldwork in their local area; others may need to arrange a residential visit. As in a laboratory, students can carry out full investigations in the field, or carry out specified practical experiments. Organising field work can be difficult because of the time involved if an off-site visit is needed. Science teachers may be reluctant to lose class teaching time and other subject teachers, who may feel under similar pressure to cover course content, may be reluctant for students to miss their lessons. The Field Studies Council tell us that “there is a very worrying decline in the quantity and quality of fieldwork being provided for students studying biology”.⁵⁹ The National Curriculum suggests that students carry out field work, but it is not required. Schools could be encouraged to use fieldwork to fulfil the coursework requirements at GCSE. **We endorse the view of the Field Studies Council that fieldwork should be strongly recommended in all courses.**

36. The Science Museum on-line survey found that the majority of students (71%) enjoyed practical work and 79% reported that practical work had helped them to understand their science. Charlotte Whitaker, a student at Redland High School, Bristol told us that “you are able to link the practical that you have done with your theoretical knowledge and it helps so much to be able to [make] that link”.⁶⁰ Hannah Greensmith, a student at Birkenhead High School, Wirral told us that she found dissection in biology particularly useful because “it gives you hand-on experience working with what you are learning about”.⁶¹ Many of the teachers that we have spoken to see practical work as a fundamental part of their teaching. James Salmon from the Anglo-European School, Essex told us that “We want children to do as much practical as possible because they enjoy it, it motivates them and it gives them skills that they can use later on”.⁶² Michael Terry from Copthall School, Barnet said that “Good quality science teaching requires extensive opportunities for practical and investigative science”.⁶³

37. However, not all students enjoy the practical work they are required to do for GCSE. Ashley Clarkson from Bede Sixth Form College, Teesside encapsulated the view of many students that we have spoken to: “all [practical work] did was create variety in the course,

⁵⁸ TIMSS 1999 International Science Report, Chapter 6, figure 6.9. Available via isc.bc.edu/timss1999.html

⁵⁹ SED20 Unprinted evidence. See also Ev 136, Appendix 21

⁶⁰ Q130

⁶¹ Q85

⁶² Q232

⁶³ SED70 Unprinted evidence. See also Ev 93, para 7.1; Ev 94, para 4

and variety is good everywhere in education because it helps you remember things more clearly".⁶⁴ Sajad Al-Hairi from North Westminster Community School in London wanted to see more variation within the practical work itself: "If there were a range of experiments that gave you a different approach and helped you experiment and research more, that would help".⁶⁵ The Head of Physics at St Augustine's College in Trowbridge, which has had considerable success in attracting girls to science, suggested that girls in particular were less motivated by practical work.⁶⁶ One of the most common complaints we have heard from students was expressed by Anika Lewis from Colchester Sixth Form College: "a lot of the practicals we did never worked so it did not help us, it did not show the theory in practice as it should have done".⁶⁷ Students see little point in carrying out practicals where they already know the result and are just expected to follow instructions to reach that end.⁶⁸ Students we have spoken to are aware that practical work is very time-consuming, leaving less room for covering the factual content of the GCSE courses. A level students from Hammersmith and West London College, who had been educated pre-16 in countries where practical work forms a very minor part of science education, told us that their theoretical knowledge was greater than that of their English counterparts. One asked what was the point of doing practical work if you did not understand the theory behind it. On the other hand, they were enjoying the opportunity to get involved with practical work at A level.

38. Derek Bell, speaking on behalf of the Association for Science Education, warned that "There is a great danger of being conned into [thinking that] the answer to it all is doing more practical work. Doing practical work in itself is not going to help children learn more effectively or motivate them. So we have to be clear why we are doing those practicals".⁶⁹ Sylvia Thomas from Darlaston Community School, Walsall supported this view when she told us that "We put practical in where we think it is needed. I do not necessarily think kids are as enthused as they were in the past about practical".⁷⁰

39. Ofsted tell us that "there is some evidence of an overall decrease in the amount of practical work, probably as a consequence of a heightened emphasis on examination requirements".⁷¹ Teachers at Quintin Kynaston School in London endorsed this view. Corinne Stevenson, a science adviser from Hounslow LEA, mentioned the other constraints. These included the poor state of some school laboratories, a shortage of technicians and the size of science classes, all of which make it difficult for teachers to manage practical lessons.⁷² We return to these issues in paragraphs 126-138 below.

40. In our view, practical work, including fieldwork, is a vital part of science education. It helps students to develop their understanding of science, appreciate that science is based on evidence and acquire hands-on skills that are essential if students are to progress in science. Students should be given the opportunity to do exciting and varied experimental and investigative work.

⁶⁴ Q176

⁶⁵ Q213

⁶⁶ Ev 203, item 3

⁶⁷ Q131

⁶⁸ Ev 200

⁶⁹ Q349 See also Ev 161, para 11

⁷⁰ Q271

⁷¹ Ev 135

⁷² Qq233 and 234

Problems with coursework

41. Students at Quintin Kynaston School, London told us that coursework investigations accounted for most of the practical work that they carried out at GCSE. This goes some way to explaining the issues identified above. The general principle of carrying out investigations is popular with teachers that we have spoken to.⁷³ Teachers from Bolton said that investigation should be a teaching style rather than a method of assessment.⁷⁴ In practice, teachers from schools in Fareham, Hampshire said that investigations are taught and carried out to maximise exam results rather than to develop skills.⁷⁵ The topics for GCSE coursework investigations are not specified but Mike Collins, a teacher at Hengrove School, Bristol, says that the range of investigative work is narrow “largely so teachers can ensure reliability”.⁷⁶ The ’59 Club, made up of the Heads of Science at 26 independent schools, say that coursework is “testing the teachers rather than the pupils. Marks reflect how well the pupils have been coached to clear the requisite hurdles”.⁷⁷ Teachers and students that we have spoken to when visiting schools have described completing coursework as jumping through hoops and have suggested that it has almost no educational value. The ’59 Club say “the present system has become a mind-numbing and disheartening bureaucratic exercise...Practical work should be an enriching experience but instead has become a dismal slog.”⁷⁸ **The way in which coursework is assessed for GCSE science has little educational value and has turned practical work into a tedious and dull activity for both students and teachers.**

Problems with using ICT in science

42. The revised National Curriculum, introduced in September 2000, for the first time required Information and Communication Technology (ICT) to be used for teaching subjects across the curriculum, including science. Illustrations given in the National Curriculum of how ICT could be used for teaching science include using data handling software to analyse data from fieldwork, using the internet to find out about current developments and issues and using automatic datalogging equipment to record results. DfES’s memorandum states that “the investment we are making in ICT is transforming the way science...is being taught”.⁷⁹ They give interactive whiteboards as an example of where developments in ICT “allow teachers to access data and images and share [them] with the whole class, in a way not before possible”. Indeed, when we visited Quintin Kynaston School in London we were impressed by the use made of interactive whiteboards. However, the lack of time available for training meant that those teachers who were confident using the technology were not able to pass these skills on to the other staff. Teachers from schools in Bolton said that they particularly needed more support from technicians with expertise in ICT. They were having to prepare “backup” lessons in case the ICT equipment failed.⁸⁰ Michael Terry, a teacher at Copthall School in Barnet, tells us that the “increased emphasis on teaching using ICT [has been introduced] without any understanding of the practical difficulties involved in using ICT in the classroom”.⁸¹ This is reinforced by Sylvia Thomas, a teacher at Darlaston Community School, Walsall, who tells us that “ICT requirements are impractical in all schools I have worked in”.⁸² **ICT may**

⁷³ For example Q244, Q265, Q312

⁷⁴ Ev 200

⁷⁵ Ev 196, para 3

⁷⁶ SED65 Unprinted evidence

⁷⁷ Ev 207

⁷⁸ *Ibid.*

⁷⁹ Ev 126, para 46

⁸⁰ Ev 201

⁸¹ SED70 Unprinted evidence

⁸² SED62 Unprinted evidence

have the potential to revolutionise science teaching but the evidence would suggest that it has not yet had a real impact in many schools.

43. The Science Museum's survey of young people asked about their use of the internet in science. While 44% reported enjoying using the internet for research, only 8% thought that it was a useful way of learning. Joel Brown, a student at Dixons City Technology College, Bradford told us "Everybody likes going on the internet and surfing around but in terms of how effective it is we are really concerned".⁸³ Mark Towers, a student at Farnborough Sixth Form College in Hampshire, thought that the problem was that while it was possible to find lots of information using the internet "it does not really have any relevance because it is of a standard that is beyond you at that time".⁸⁴ The BBC Bitesize website, which is specifically designed for students revising for their GCSEs, was mentioned to us by several students at Quintin Kynaston School, London as one that they had found useful. It is not enough to invest in computers for schools. If students are to gain skills that will be useful to them in the future, ICT needs to be used intelligently to support other subjects areas. **There needs to be a clearly defined role for ICT within science teaching if it is to have any real educational value.**

⁸³ Q182

⁸⁴ Q186

TAKING SCIENCE POST-16

44. Problems with science education at 14-16 have a knock-on effect on science post-16, affecting both students' subject choices and the required content of courses following on from GCSE. What has come across from our discussions with students is that those who are continuing with science post-16 often do so in spite of their experiences at GCSE. They are frequently motivated by a longer term ambition to follow a particular career, which requires them to have studied sciences at A level. Many of the young scientists we surveyed at the Royal Society of Chemistry reported that they had found science at GCSE boring. **It would seem that students study science post-16 not because of science at GCSE but despite it.**

45. Many of the issues raised with us about post-16 courses themselves relate to the implementation of the recent AS and A level reforms. In particular we have been told about the difficulty of completing the AS courses in time for exams that fall in January and May, concern that an excessive amount of time is spent on exam preparation and concern about the pressure that the exam system places on students.⁸⁵ These are very important issues but are not science specific.

Falling popularity

46. The take-up of the sciences post-16 is a widely discussed area and the general assumption is that the number of students studying science at A level is falling. An analysis of the statistics is presented in Annex 3.⁸⁶ Science subjects are popular at A level. 60% of A level candidates enter at least one science or maths A level.⁸⁷ English is the A level taken by the greatest number of students, followed by maths, biology and chemistry. The numbers of students choosing biology, chemistry and physics post-16 has been fairly static for the last 5 years, following a significant drop in the take-up of physics prior to 1996.⁸⁸ However, the proportion of A level entries accounted for by chemistry and physics is falling.⁸⁹ This matters because young people are, at age 16, closing off the option of entering a career in science or engineering at a time when the UK is suffering from a shortage of scientists and engineers.⁹⁰ Physics A level has seen the most marked decline in popularity, while biology has largely retained its popularity. Throughout the late 1980s physics was the most popular science A level; it now attracts a third fewer entrants than biology A level. The Head of Biology at St Augustine's Catholic College, Trowbridge said that biology A level attracted many "humanities types" for whom biology was their only science subject.⁹¹

47. It was hoped that the introduction of AS levels in 2000 would have encouraged more students to choose to continue with science for a further year post-16. It is difficult to establish at this early stage if this is happening. The statistics record only those students that have "cashed in" their AS results and accepted their grade: students can choose not to cash in their AS results so that they can retake modules and improve their marks. In addition, at Westminster School, the Head of Science told us that he had decided not to enter students for AS chemistry exams after their first year of study, but to enter them for AS and A2 exams together at the end of the two year course. If these options were not available, the total number of entries for AS levels would be expected to be considerably

⁸⁵ Ev 85, para 6; Ev 117, para 22; Ev 139 para 4.2

⁸⁶ See p 81

⁸⁷ Figure A8, Annex 3

⁸⁸ Figure A1, Annex 3

⁸⁹ Figure A3, Annex 3

⁹⁰ Discussed in the Roberts Review, chapter 1.

⁹¹ Ev 203, item 4

higher than that for A levels: students were expected to study four or five subjects to AS level, as opposed to the standard three to A level. However, in 2001, there were 686,000 entries to A levels compared to a total of 647,000 entries to AS levels.⁹² This pattern is reflected in the entries to the sciences. For example, 33,650 students entered chemistry A level, while 30,986 students entered the new chemistry AS level. While it not possible to draw any firm conclusions because the statistics do not show a true picture of the number of students studying AS levels, **it seems that recent reforms to post-16 education have not produced a significant increase in the number of students studying sciences.**

48. We discussed the take-up of science in Scotland on our visit to Beeslack High School in Penicuik. In Scotland, Standard Grade at age 16 is broadly the equivalent of GCSE, after which students generally choose 4-5 subjects to study as Highers. In recent years there have been significant decreases in the take-up of biology, chemistry and physics for Scottish Highers although, after English and maths, chemistry, physics and biology are the most popular choices.⁹³ The take-up of science A levels in England is comparatively healthy.⁹⁴ In Scotland, students are expected to study at least one science to Standard Grade at age 16 but are free to opt between the sciences: 70-75% of students choose to study only one science.⁹⁵ They may therefore be limiting their choices post-16 at the age of 14. At the same time, each of the sciences attract almost identical numbers of entries in Scotland. We do not know the cause of the disparate interest across the sciences in England but the contrast with Scotland is striking. Possible factors include the chronic shortage of physics teachers in England, an issue not yet affecting Scotland, and a different approach to the curriculum and its assessment up to age 16 and post-16.

49. It is at university level that the big decreases in take up have been seen in some areas of science and engineering. Between 1995 and 2000, while there were increases in the number of students studying biological sciences at undergraduate level, the number of entrants to chemistry degrees fell by 16% and to physics and engineering degrees by 7%.⁹⁶ This reflects a trend seen in other countries. A recent report on young people and science in France concluded that there was no evidence that students were shunning science at secondary school. On the other hand, between 1995 and 2000 the number of students entering university in France to study physics and chemistry fell by almost 50%.⁹⁷

Gender

50. All students now study biology, chemistry and physics up to age 16. Girls now perform as well, or better, than boys in science at every examination stage from ages 11 to 18. For example, 53% of the girls entered for double science GCSE in 2001 passed with grades A*-C, compared to 50% of boys.⁹⁸ The Equal Opportunities Commission regards “girls’ participation and achievements in science to age 16...as one of the recent success stories of education”.⁹⁹ It is when students are able to make subject choices at age 16 that it becomes apparent that boys and girls are not equally engaged across the sciences.¹⁰⁰ Girls significantly outnumber boys in biology A level and, if the current trend continues, may soon outnumber boys in chemistry too. In physics, the proportions have been static over

⁹² GCSE/GNVQ and GCE A/AS/VCE/Advanced GNVQ Results for Young People in England 2000/2001. DfES. November 2001. Tables 11 and 13. AS level figures are for students aged 16 at the start of the academic year; A level figures are for students aged 17-18 at the start of the academic year. Available via www.dfes.gov.uk/statistics

⁹³ Figure A5, Annex 3; Ev 129 para 12

⁹⁴ Figure A6, Annex 3

⁹⁵ Ev 128, para 10

⁹⁶ Roberts review. Paragraph 0.27 and figure 1.5.

⁹⁷ SED104. Unprinted evidence

⁹⁸ See Ev 144 for comparative data on performance at A level.

⁹⁹ Ev 147, para 32

¹⁰⁰ Figure 4, Annex 3

the last 8 years, with girls continuing to make up only 20% of the entries. This matters because it implies that girls are being excluded from physics and because the shortfall of scientists and engineers will be most easily addressed if there is representation from the whole, rather than only part, of the population.¹⁰¹ Biology is sometimes seen as a good way to attract students, in particular girls, into science, but A level biology alone does not provide a route in to the physical sciences.¹⁰² **We welcome the increase in the number of girls studying biology and chemistry to A level that has occurred since the introduction of compulsory balanced science to GCSE. In particular we are pleased that girls now make up 50% of A level chemistry entries. We are, however, concerned that physics remains an unpopular option with girls.**

51. The number of boys choosing A level physics has, after decreasing for several years, remained relatively static since 1996. In contrast, the number of boys choosing to study biology and chemistry has been falling for the last four years. Indeed, the equal representation of boys and girls in chemistry A level would not have occurred without this decrease in entries from boys. In biology, the number of entries from boys remains above that of the early 1990s in spite of recent decreases. But boys continue to make up less than 40% of entries. We have no explanation for the falling popularity of the sciences for boys other than that they are presumably more attracted to other subjects. DfES suggested that take-up of computer science in particular, which has increased by 128% over the last 10 years, might at least be a partial explanation.¹⁰³ In 2001, computer studies A level was taken by 15,051 boys, while 21,751 boys sat physics A level.¹⁰⁴ **The falling number of boys choosing biology and chemistry A level is a matter for concern. The reasons for this need to be investigated further and we recommend that DfES fund research in this area.**

52. Students' explanations for the gender differences in take-up of sciences have been mainly in terms of career aspirations. Students from Hammersmith and West London College thought that boys were more likely to want to move in to "techie" careers that would need physics. And girls are associated with caring professions such as nursing, which require biology, and medicine, which requires both biology and chemistry.¹⁰⁵ Girls' choices may reflect the lack of visible female role models, which is discussed further in paragraph 123. From a teacher's perspective, Michele Ryan, a teacher at Ricards Lodge High School in Wimbledon, felt that "girls do tend to be more interested in biology topics, they are more interested in topics that they can personally relate to".¹⁰⁶ She said that, in comparison, "there is a view that boys are more [interested in] knowledge for the sake of knowledge".¹⁰⁷ In research carried out by King's College, London, boys and girls alike felt that changes were needed to the science curriculum, primarily to introduce more modern ideas.¹⁰⁸ But the examples that they gave were distinct, with girls wanting more emphasis on advances in medical science and boys interested in topics such as nuclear fission and fusion. Astronomy was the one area that both boys and girls mentioned.¹⁰⁹ **The GCSE science curriculum fails to provide for the differing interests of boys and girls.**

¹⁰¹ Ev 143, paras 7-8

¹⁰² Ev 203, item 4

¹⁰³ Q537

¹⁰⁴ Source: Joint Council for General Qualifications. Candidates of all ages in England.

¹⁰⁵ See also Ev 145, para 20

¹⁰⁶ Q251

¹⁰⁷ Q252

¹⁰⁸ Pupils' and Parents' Views of the School Science Curriculum. 2000. King's College London.

¹⁰⁹ See also Ev 132, para 7; Ev 140, Appendix 24

Ethnicity

53. There are also differences in take-up of post-16 science among ethnic groups. These are no doubt affected by experiences and attainment at GCSE. The African-Caribbean Network for Science and Technology has presented data to us showing the differing levels of attainment in science and mathematics of students from different ethnic minority groups in science, based on data from Birmingham, Manchester, Nottingham and the London Borough of Enfield. The results present a complex picture.¹¹⁰ For African-Caribbean pupils, a high level of achievement in the early years is followed by decline and underachievement at GCSE, with a marked gender differential in favour of girls. Indian and Chinese pupils achieve high levels of attainment throughout: Chinese girls and boys do equally well, while Indian girls do better than boys as they get older. Pakistani and Bangladeshi pupils have the lowest levels of attainment on entry to school but do better than the African-Caribbean pupils by the GSCE stage, with girls doing better than boys (most markedly among Pakistani pupils).

54. Some LEAs, as shown above, have collected data on the performance of students by ethnic group. This has not been the norm. Schools have been required to report the number of ethnic minority students on their school roll, by ethnic group, to DfES since 1990. However, this information was not linked to the performance of individual students and so was little more than a head counting exercise. In January 2002 DfES introduced the Pupil Level Annual School Census, which requires schools to provide data on an individual pupils, rather than for their school overall. This has meant a considerable amount of extra work for some schools. Once the new census is fully introduced it should allow data on, for example, achievement at GCSE, to be cross-referenced with ethnic group on a school, LEA and national level. **We welcome the introduction of pupil level ethnic monitoring by DfES. We trust that the data will show the performance of different ethnic groups in science subjects and recommend that this information will be made public as part of DfES's annual statistics publications.**

55. Data from the Further Education sector – which already conducts ethnic monitoring – presents a complex, and in some respects surprising, picture.¹¹¹ Black Caribbean pupils are proportionately represented on science, engineering and technology courses at further education, but show the lowest level of achievement in science. Black Caribbean females have higher enrolment rates than males in all subjects, even construction and engineering. In construction and engineering, which are traditionally seen as male-dominated areas, it is only among white pupils that males outnumber females. **It would appear that some of the usual assumptions about the relative participation of men and women in science and engineering are simply not true in respect of ethnic minority students.**

56. The African-Caribbean Network raises a number of curriculum issues affecting the differential attainment of ethnic minority students. It is argued that the science curriculum is eurocentric, ignoring the contributions of other cultures to science, and that textbooks and other teaching resources in maths and science are produced with little awareness of the dangers of reinforcing racist stereotypes. Teacher expectation discourages black children from achievement in maths, science and technology (while, conversely, Asian pupils are expected to achieve in these areas and discouraged from achievement in the arts and humanities).¹¹² Racial stereotyping is also reported in careers guidance: even well-qualified black students are rarely encouraged to take up careers or further study in numerate or technical fields. The Network reports that there is evidence that African-Caribbean pupils are disproportionately over-represented in the pupils for whom science and design and

¹¹⁰ Ev 147, Appendix 27. Graphs not published.

¹¹¹ *Ibid.*

¹¹² Ev 150, para 1.14

technology are disappplied at Key Stage 4: in other words they would not study these subjects to GCSE.¹¹³

Difficulty of A level sciences

57. Among the factors affecting A level choices are the perceived difficulty of science subjects and the increasing availability of alternative courses in other subject areas. Students and teachers have told us that science A levels have a reputation for being harder work than other subjects and that it is more difficult to pass science A levels than some other subjects.¹¹⁴ Students from Hammersmith and West London College mentioned in particular the amount of time they invested in coursework for science A levels, which they said was considerably more onerous than for peers studying subjects such as business studies. As Ed Walsh, a teacher at Roseland Community School in Truro told us, there is a risk that this can “almost become like a badge of honour” and increase the sense of elitism around science.¹¹⁵ The Roberts Review reported on-going research, carried out through the ALIS project at the University of Durham, which showed that sciences, foreign languages and mathematics A level courses attract, on average, students who have done better at GCSE than sociology, psychology or law.¹¹⁶ The Durham research also suggests that it is more difficult to achieve grades in some A level subjects than others. On average, students with the same GCSE profile will achieve one grade lower in chemistry, physics and maths than the average A level grade obtained. This is not unique to science. The most difficult subjects, based on a comparison of achievement at GCSE and A level, in roughly this order, are chemistry, physics, Latin, French, maths and biology. This will vary from year to year, but remains fairly stable. Most students are likely to be discouraged from studying a subject that they think will be harder than others. This may be particularly true for those students who do not intend to move into an area that requires qualifications in science but who are looking to accumulate the best overall point score for university entrance. The Head of Biology at St Augustine’s Catholic College, Trowbridge felt that biology A level was seen as an “easy option” compared to the other sciences and therefore attracted students of a wider range of abilities.¹¹⁷ **Students may be dissuaded from studying science at A level if they think it will be harder work than other subjects and more difficult to achieve a high level grade.**

Maths skills

58. Some students appear to be put off doing science post-16 by the mathematical content of A level science courses. This does not seem to be a problem at GCSE. The Science Museum’s on-line survey of young people suggests that GCSE students are generally confident in their ability to use maths. 79% reported that they had not struggled with the maths requirements in GCSE science. Susan Turner, a teacher at Bishop David Brown School, Woking told us that “The content of the [GCSE] syllabus is now far less mathematical than it was”.¹¹⁸ The problems seem to arise post-16, where the mathematical demands, particularly in physics, are higher.

59. Lucy Ferguson, a student from Guildford High School, said that one of the things that might have led her to choose science A levels would have been “less maths”.¹¹⁹ Catherine Wilson, from the Institute of Physics, saw this as a particular issue for physics A level,

¹¹³ Ev 154, para 1.32

¹¹⁴ For example Ev 94, para 5; Ev 164, para 33; Ev 203, item 3; Ev 201

¹¹⁵ Q273

¹¹⁶ Roberts Review. Paragraphs 2.105-2.106

¹¹⁷ Ev 203, item 4

¹¹⁸ Q279

¹¹⁹ Q211

where students need to take maths as well if they are considering continuing with physics post-18.¹²⁰ Rubens Reis, a student at St Augustine's School, London, told us that "Maths is not something you do for fun but because you have to".¹²¹ Similar sentiments have been expressed by other students. Tim Crocker-Buque from Worthing Sixth Form College told us that "definitely maths is just a servant to the sciences".¹²² **The mathematical requirements, or students' perceptions of the mathematical requirements, of A level sciences puts students off choosing to study these subjects. This particularly applies to physics.**

60. On the other hand, universities and employers say they need people who are better able to use maths. Stuart Brown from Nottingham Medical School told us that the maths their students need would have been learnt at ages 14 to 15 but that "the trouble is that it is not reinforced sufficiently so that when they get to university they say they have either not heard of it or they have forgotten".¹²³ For physical, rather than bio-medical, sciences the issue is somewhat different. Cambridge University's School of Technology tell us that physics is "inherently detailed, quantitative and, sometimes, difficult. This is largely hidden from students at school, so that the nature of a university course can come as a great shock to them".¹²⁴ They describe this as the "demathematisation" of school science teaching.

Making an informed choice

61. Some students have told us that they gain little understanding at 14 to 16 of what the subjects involve at A level. Students at Quintin Kynaston School, London told us that, within the double science GCSE course, the difference between biology, chemistry and physics was not spelt out to them. Teachers in Fareham, Hampshire suggested that students may find it difficult to distinguish the boundaries between subjects where teachers teach across subjects.¹²⁵ The Association of Colleges tell us that "this hampers their ability to make an informed choice about what disciplines they should select to pursue..., and what this study will demand of them".¹²⁶ Indeed, one student we met at Quintin Kynaston was dropping chemistry after AS level because the course was not what she had expected. More positively, another reported that she was enjoying A level sciences much more than she would have expected from her experiences at GCSE.

62. Students' choices post-16 are influenced by the career that they aspire to. Ashley Clarkson from Bede Sixth Form College, Teesside told us that "You really only go on to study science if you wanted a job which was to do with science".¹²⁷ Research carried out by the National Institute for Careers Education and Counselling (NICEC), found that "Generally it was only if pupils knew they needed sciences for a career choice (medicine being a common example) would they be determined to study science".¹²⁸ The same research found that "subject choices were being made with little understanding of the range of work and study opportunities open to people with science and technology qualifications nor of the educational or personal advantages". Students were not aware that science could provide valuable transferable skills, opening doors to a wide range of non-scientific careers. Indeed one student at Westminster School told us that science had little to offer in the way

¹²⁰ Q5

¹²¹ Q110

¹²² Q117

¹²³ Q387

¹²⁴ SED33 Unprinted evidence. See also Ev 140, Appendix 24

¹²⁵ Ev 196, para 2

¹²⁶ Ev102, para 110

¹²⁷ Q165

¹²⁸ SED6. Unprinted evidence. Choosing Science at 16: The influences of science teachers and careers advisers on students' decisions about science subjects and science and technology careers. 2000. Published by CRAC.

of transferable skills because, unlike subjects such as history and English, you were not taught to think for yourself. Students do not in general choose history A level with the expectation that they will become historians but the sciences are to a great extent chosen by those who expect to pursue scientific careers.

63. Influences on career ambitions are wide-ranging; the NICEC report mentions parents and family, the image of science, the image of jobs in science and engineering, the history of the local labour market, gender and the media. Careers in science are not perceived to be glamorous or financially rewarding. Together with students' experiences in the classroom, these factors determine students' choices post-14 and post-16. At 14 there is no choice to be made about science and discussions about educational and career value focus on subjects such as geography and ICT, where there are decisions to be made.¹²⁹ Interviews with careers advisers usually occur after the first year of GCSE, by which time NICEC reports that most students have already decided whether to continue with science post-16. The report also said that young people found interviews with careers advisers most useful where they wanted further information about a career in which they were already interested. Young scientists that we spoke to at the Royal Society of Chemistry told us that they had received very little careers advice in school. **Students' awareness of scientific careers and the value of transferable skills gained through science would appear to be limited.**

Vocational pathways

64. Traditional A levels are not appropriate for all students post-16. The main alternative, GNVQs, have never attracted students on a significant scale. The Nuffield Foundation suggest that this "failure was not due to a lack of interest from teachers" but because "when they offered these courses they could not recruit enough students to make them viable".¹³⁰ They suggest that the attraction for teachers "was not so much because they were 'vocational' but because they offered an alternative approach to teaching, learning and assessment" that would help to motivate students.¹³¹ However, from a student's perspective, it was not clear where a broad vocational qualification in science would lead. The GNVQ in health and social care, which has a basis in the biological sciences, has attracted more entrants perhaps because students can see a direct route to the caring professions. Given this, and the low status currently given to vocational education, it is perhaps not surprising that students have not been attracted to vocational science courses.

65. The first VCEs, the replacement for advanced GNVQs, were taught from September 2000. Chris Roberts from Bradford FE College told us that, with the change from GNVQ to VCE, the approach "has drifted closely to that [of A levels] and it is turning students off".¹³² The Association of Colleges tells us that "colleges have needed to set an entry standard as high, or in some cases, higher than for AS/A level study".¹³³ In the effort to achieve equal status for academic and vocational qualifications it seems that the distinctive nature of vocational education is being lost. The unexpectedly low pass rate for the first students sitting VCE exams in 2001 has also discouraged students. **The vocational options in science are not yet attracting students. More should be done to provide attractive vocational courses and to ensure that students are well aware of the potential value of the qualifications for a range of future careers.**

¹²⁹ See also Ev 93, para 5.1

¹³⁰ Ev 157, para 31

¹³¹ *Ibid.* para 32

¹³² Q328

¹³³ Ev 98, para 51

Universities' views

66. From the perspective of universities, Stuart Brown, from Nottingham Medical School, told us that he felt that there had been “a decline in the knowledge base” of A level students.¹³⁴ This is a commonly heard criticism and one that it is difficult to pin down. QCA recently invited an independent panel of advisers to review the quality assurance arrangements for A level. They published their findings in January 2002 and concluded that “there is no scientific way to determine in retrospect whether standards have been maintained. Therefore, attention should be placed on ensuring the accuracy, validity and fairness of the system from now on”.¹³⁵

67. The science taught and assessed in A level courses seems to have kept up with the modern world somewhat better than GCSE. However, Roberts reports that “reductions in the depth of knowledge required at A-level in favour of breadth and relevance of study, are seen by some to weaken the usefulness of the A-level as an indicator of a student’s ability to tackle the more complex and in depth work at degree level”.¹³⁶ The view that there has been a loss of depth at A level was also reflected in comments from schools. A physics teacher at Westminster School criticised the new Advancing Physics A level developed by the Institute of Physics. He told us that, while the course brought interesting contemporary physics into the classroom, he perceived a loss of depth. Teachers at St Augustine’s Catholic College, Trowbridge said there had been an element of “dumbing down” in recent curriculum developments, and wanted to see the curriculum made more relevant to daily life.¹³⁷

68. As only 50-60% of the content of an A level course is specified by QCA, students may arrive at university having covered very different material at A level. This applies not only to students who have been taught different specifications: there is often the freedom for teachers to select modules from within a specification. Ian Haines, representing the UK Deans of Science Committee, told us that he would like to see more common material between different A level specifications so that he “could guarantee a certain amount of subject knowledge”.¹³⁸ This problem is further exacerbated by the trend for students to take a combination of science and non-science subjects at A level.¹³⁹ The recent reforms at AS and A level, described in paragraph 18, are intended to encourage students to broaden the range of subjects that they study post-16. Undoubtedly a broad education has its benefits, but at the same time university science and engineering departments want depth. Tom Ruxton of the Engineering Professors’ Council told us that “a chartered engineer would need a depth of science at A level – physics, chemistry, maths”.¹⁴⁰ **Where universities place restrictive demands on applicants, specifying grades in three A level subjects, students are unlikely to place value on broadening their education.**

¹³⁴ Q377

¹³⁵ The full report can be seen at www.internationalpanel.org.uk

¹³⁶ Roberts Review, para 3.2

¹³⁷ Ev 202, para 1

¹³⁸ Q378. See also Ev 139, paras 3.11-3.13

¹³⁹ Imagination and Understanding: A report on the Arts and Humanities in relation to Science and Technology, Council for Science and Technology, 2001. Available via www.cst.gov.uk. See also Ev 164, para 34.

¹⁴⁰ Q384

14 TO 16: THE WAY AHEAD

Timetable for change

69. The problems affecting science at 14-16 are clear: the difficult issue is how these can be tackled. Changes in the curriculum cannot be achieved overnight: teachers need to know of any changes before they start teaching a two year GCSE course so that they can prepare their teaching appropriately. The revised GCSEs, which are being examined for the first time in 2003, should address some of the issues about which we have raised concerns. We therefore expect that the GCSE assessment in 2003 will look noticeably different from that in 2002. Other proposals, such as the review of the National Curriculum, will need more time for development, including genuine consultation with teachers. We see no reason why these discussions should not start immediately, with a view to seeing conclusions implemented from 2005.

Rethinking assessment of the current GCSEs

The awarding bodies

70. Assessment at GCSE is the responsibility of the three awarding bodies, overseen by QCA. When we first sought evidence from the awarding bodies they told us simply that they “believe that the choice of specifications...meets the needs and aspirations of centres”.¹⁴¹ When invited to justify this statement they subsequently told us that they recognised that “there is a need to include more up-to-date ideas”; that “the applications of science should be highlighted more strongly”; and that there were problems with both practical work and the current single science GCSE.¹⁴² To this we would add that the specifications are overloaded with factual content and lack flexibility. Exam courses should encourage the development of the skills of comprehension, evaluation and synthesis of scientific ideas and information, as much as they do the recall of scientific facts. While the responsibility for the excessive factual content could be blamed partly on the National Curriculum, most of the problems lie with the methods of assessment imposed by the awarding bodies.

71. Some development work is being undertaken at GCSE. OCR are developing an alternative approach to single science GCSE and are also working with QCA on the pilot of a new approach to GCSE science. But overall the awarding bodies seem to be doing remarkably little to resolve to the problems with GCSE science. **We are amazed that the awarding bodies take so little responsibility for finding solutions to problems with GCSE science that they themselves have caused. We take little comfort from their ability to identify these problems when they show little initiative in addressing them. Government should make plain to the awarding bodies that the future accreditation of their science GCSE courses depends on them developing imaginative alternative ways of assessing science at GCSE. Any changes to the National Curriculum will have limited impact on the way science is taught in schools if the assessment is not changed too.**

¹⁴¹ Ev 118, Appendix 14

¹⁴² Ev 118, Appendix 15

The QCA

72. It is QCA's role to regulate qualifications and they should therefore take final responsibility for the problems that we have identified with science at GCSE. Keith Weller of QCA told us that "it may be... that the examinations do not always do full justice to the specifications they go with, or indeed, to the curriculum they sit alongside".¹⁴³ If that is the case, then QCA should have stepped in to ensure that the awarding bodies changed the way that they assessed science. The quinquennial review of QCA, published in June 2002, recommended that QCA increase its focus on assessing the capability of awarding bodies to fulfil their role, and step back from detailed involvement in individual qualifications.¹⁴⁴ Certainly QCA should give more attention to the capability of the awarding bodies to develop and implement innovative ways of assessing science at CSE. **QCA's lack of direction has allowed assessment of GCSE science to stagnate. QCA should now set out clearly what they expect of awarding bodies offering science GCSEs and should intervene where these criteria are not met.**

Introducing flexibility to the exams

73. As discussed in paragraph 25, the perception of teachers and students alike is that GCSE science exams are based largely on the recall of facts. The GCSE specifications go into some detail about exactly what students should know and teachers go to every effort to cram all this information into the two year course. This leaves little time to explore areas outside the exam course, leaving teachers and students frustrated. Following our evidence session with QCA and the awarding bodies, when we raised these issues, we were sent some examples of questions used at AS and A level in science.¹⁴⁵ One example asked students to answer questions using any appropriate case study that they had covered. A second asked students to write an analysis of a modern application in science using chemical principles learnt during the course, articles provided by the awarding body and further independent research. In these examples, up-to-date science and its applications were used as exam contexts, teachers would have had flexibility in the specific examples that they use in their teaching, and students were required to demonstrate that they could think and apply their knowledge and understanding rather than just regurgitate facts.

74. The awarding bodies told us that it required a minimum of three years to introduce developments in science to GCSE specifications and exams, since teachers needed to know well before the beginning of the two year course what their students would be examined on at the end.¹⁴⁶ Martin Hollins from QCA told us that it would be possible to bring contemporary science into GCSE more quickly if there was a move away from factual recall questions.¹⁴⁷ If GCSE exams were to use a wider range of questions, including some that gave flexibility in the answers that students could offer, this could do much to free up teaching at key stage 4. GCSE exams should also test skills that will be more useful to young people than the ability to learn facts parrot fashion. Similar approaches to assessment are used at GCSE in subjects such as history and humanities. It is surprising that they have not been adopted in GCSE science as well.

75. Teachers from Fareham in Hampshire said that a specimen question produced for the new GCSEs in 2003 showed a welcome shift towards ensuring that students had the intellectual tools to assess future science issues. This specimen is likely to have been

¹⁴³ Q461

¹⁴⁴ Qualifications and Curriculum Authority: Quinquennial Review 2002. Chapter 7, paragraphs 3-7. Available via www.qca.org.uk

¹⁴⁵ SED 42. Supplementary memorandum, unprinted

¹⁴⁶ Q472

¹⁴⁷ Q475. See also Ev 116, para 17

approved by QCA at the same time as the new specification. QCA now needs to ensure that all awarding bodies implement and sustain such an approach when it comes to setting actual exam papers. **QCA should require awarding bodies to introduce a wider range of questions to GCSE science exams. These should enable issues raised by contemporary science to be used as the focus for questions; allow flexibility for students in their answers; and, most importantly, they should test a wider range of skills than the mere recall of facts.**

Widening the range of coursework

76. Coursework arrangements for GCSE science are at present pointless and tedious and must be changed. One option would be to do away with coursework altogether. It is clear that teachers and students see practical work as a fundamental part of science education, which helps students to gain understanding, and so it can be assumed that teachers would continue to use practical work as a key part of their teaching even if it were not formally assessed as part of GCSE. Getting rid of coursework would allow teachers to use practical work as and when appropriate to support teaching. In key stage 2 and 3 SATs – the national tests sat by students at ages 11 and 14 – students’ investigative skills – planning experiments, interpreting data and drawing conclusions – are assessed through a written exam. It is assumed that teachers will have carried out and assessed actual practical work with their classes as a normal part of their teaching, but hands-on practical skills do not contribute to the test level awarded. A similar approach could be taken at GCSE where practical skills are not formally assessed. The risk would be that – where teachers felt under pressure to maximise exam results, they did not have adequate technical support, their laboratories and equipment were in poor condition or classes are large, the use of practical work would be reduced. Students might also be less interested in carrying out practical work if it did not contribute directly to their final mark.

77. Practical work not only helps students to gain understanding but also develops technical and manipulative skills that will be needed if they continue with science-based education or employment post-16. It could be argued that the ability to use equipment safely and accurately is in itself an important skill that needs to be assessed in its own right. In the past, these skills were tested in practical exams and this remains an option at A level. At GCSE, the numbers now entering science are probably too large to make this option logistically feasible. In any case, there is a risk that practical exams would encourage the rote learning of practical experiments, which would have little value for most students. The alternative to practical exams is to assess practical skills through coursework. **We think that it remains important to assess practical skills at GCSE through coursework. But there is no point in continuing with coursework arrangements that have little educational value.**

78. Michelle Ryan, a teacher at Ricards Lodge High School in Wimbledon told us that she would like to see students carrying out more open-ended investigations where they could get involved with “proper scientific inquiry”.¹⁴⁸ We strongly endorse this view. Students should be given opportunities to undertake inquiries where there is no predetermined answer and to contribute something to scientific knowledge. We can imagine students measuring the water quality of a local river or the incidence of butterfly species in the local area. They could collect field data over an extended period of time, possibly with the aid of ICT. Contributing to national investigations – which have looked at subjects as diverse as background radiation in homes and woodlice populations in the past – might fire students’ imagination. Linking practical work to high profile events – the solar eclipse for example – can help to engage students’ interest. We are told that, in the United States, students routinely participate in long-term science projects. The students

¹⁴⁸ Q244. See also Ev 85, para 6

select the topics themselves, which is said to foster creative thinking and an interest in science, and often present their results at school science fairs.¹⁴⁹

79. It has become the accepted norm that coursework in GCSE science means carrying out investigations. The range of coursework could be widened to include a project chosen by the student and focusing on an area in which they are interested. For example, in the AS Science for Public Understanding course, students have to write a report on a topical scientific issue of their choice and write a critical account of a popular science book that they have read. We could imagine a similar project based approach being used at GCSE. Students could be asked to produce a report on the scientific arguments for and against GM foods, MMR vaccines or an aspect of the history of science.

80. For the GCSEs being taught from 2001, QCA gave the awarding bodies the flexibility to allocate up to 10% of science assessment to coursework other than investigations. This could have included project work, but the awarding bodies chose not to take advantage of this. The awarding bodies did amend the mark scheme for GCSE coursework investigations, with the support of QCA. The changes were intended to enable teachers to be more flexible in the way that they approached coursework. QCA told us that it was too early to see if they were having any effect, or indeed if teachers had yet assessed what the changes might mean for them.¹⁵⁰

81. We recognise that coursework creates additional burdens for teachers in terms of marking and moderation. It can also raise questions about the reliability of the marks. The '59 Club, made up of the Heads of Science at 26 independent schools, suggested that "only those practical skills which cannot be tested on paper should be subjected to a system of internal assessment".¹⁵¹ Skills of planning and of analysing evidence should be tested through a written examinations, as in the SATs. They suggest that this coursework component may amount to only 10% of the final mark. This would leave the other 10% available for a more open-ended report on other aspects of science.

82. Coursework in science at GCSE needs a radical rethink. This is the responsibility of the awarding bodies but it is obvious that they are going to need significant encouragement from QCA. QCA should evaluate the coursework submitted in 2003, which will be the first to be submitted under the recently modified arrangements. If there is no significant change in the approach to investigative work, they should enter into immediate discussions with teachers and awarding bodies about how coursework could be changed to encourage more stimulating and engaging practical work in schools. In addition, we would like to see project work available to teachers as an option for GCSE coursework. This may mean reducing QCA's requirement that 20% of GCSE assessment be based on investigative skills measured through coursework.

For the future – should all students continue to study science from 14 to16?

83. The DfES Green Paper 14-19 proposes a more flexible structure for education at 14 to 19 where students would follow a range of vocational and academic courses at times that suit them during this period. To create this flexibility the Green Paper proposes removing the requirement to study a modern foreign language and design and technology between ages 14 –16; and to keep English, maths, ICT and science as compulsory subjects on the basis that they either

¹⁴⁹ See Annex II

¹⁵⁰ Q455

¹⁵¹ Ev 207

- provide an essential basis for progression and for keeping young people's options open; or
- are essential for personal development.¹⁵²

Mr Timms, the then Schools Minister, told us that “there was certainly a debate” within DfES about whether science should be kept as a compulsory subject within this flexible 14 to 16 framework.¹⁵³ **We are convinced that science is essential for progression and for personal development and welcome DfES’s decision to keep science as a compulsory element of the curriculum from ages 14 to 16.**

84. In the foreword to the Roberts Review, Sir Gareth Roberts says that “scientists, mathematicians and engineers contribute greatly to the economic health and wealth of a nation. The UK has a long tradition of producing brilliant people in these areas.”¹⁵⁴ He raises concerns that the decline in the numbers studying physics, maths, chemistry and engineering at university level “could undermine the Government’s attempts to improve the UK’s productivity and competitiveness”. We agree. Many government initiatives, such as modernisation of the health service and the development of high tech industries, rely on a body of knowledgeable and skilled scientists, engineers and technologists. Science at school should inspire and prepare students to continue with science related careers. But this is not all. The skills that science education provides are highly valued and scientists are in demand across the economy. Further, science is an integral part of our culture, vital to the understanding of the world around us and a source of inspiration and wonder. Science and technology have a huge impact on our everyday lives and as new developments occur and new possibilities open up there is, and will continue to be, public debate on how these should be used. Everybody needs to be able to recognise the impact of science and technology and to participate in an informed way in the debates on the direction of future developments. **The challenge at 14 to 16 is to provide a secure foundation for those moving on to further scientific study post-16 and to give an understanding of science to those who do not; that is, to meet the needs of future scientists and of citizens.**

85. The Green Paper also outlines proposals for a new matriculation diploma, which would draw together and recognise qualifications and experiences gained by young people between ages 14 to 19.¹⁵⁵ It suggests that students should be able to matriculate at different levels, depending on their achievements, and that both taught and work-based qualifications would be counted. For example, to matriculate at intermediate level, students would either need five good GCSEs or a foundation modern apprenticeship diploma. The Green Paper suggests that in order to gain any diploma, students would have to show competence in literacy, numeracy and ICT. No mention is made of science. Given the decision to keep science, as well as English, maths and ICT, compulsory to age 16, this seems illogical. While ICT is important, science and technology remain vital for the economic wellbeing of the country. In order to matriculate, students should demonstrate that, between ages 14 and 19, they have studied a balance of biology, chemistry and physics to an appropriate level. Most provinces in Canada require students to have gained science credits in order to graduate from school at age 18.¹⁵⁶ Many students gain the necessary credits pre-16 and we can imagine the same situation applying in England. For those students who did not achieve the matriculation requirements for science in England pre-16, further thought may need to be given as to how they could be supported to achieve this. This would apply particularly to students following work based courses post-16, such as modern apprenticeships. **Having taken the decision to keep science compulsory to age 16, DfES should include science in the requirements for any matriculation diploma.**

¹⁵² Green Paper 14-19, paragraphs 3.9 and 3.10

¹⁵³ Q502. See also Ev 92, para 2.6

¹⁵⁴ Roberts Review, foreword

¹⁵⁵ Green Paper 14-19, chapter 4

¹⁵⁶ See Annex II

What science do all students need?

86. The scientific learned societies argue that pupils should have an “understanding of key areas of science in relation to the ways in which it affects their lives, society and world in which they live”.¹⁵⁷ Students need to have acquired knowledge and skills beyond the ability to remember scientific facts. This is described by the Wellcome Trust and others as “scientific literacy”.¹⁵⁸ Defining scientific literacy – or what an individual would need to be able to do in order to be scientifically literate – is not straightforward. For instance, the Nuffield Foundation asks “what did the citizen need to understand, for example, to come to a sensible decision about whether to eat beef during the BSE crisis? What does a parent need to know to come to a decision about MMR vaccination?”.¹⁵⁹ Research has shown that the knowledge of science that school currently provides is of little value when considering these issues. In addition, much of the scientific knowledge acquired at school is forgotten by adulthood.¹⁶⁰ Rather, what is needed is a much better understanding of the practices, processes and limits of scientific knowledge. Developing such an understanding is essential if individuals are to be able to make personal decisions and to participate in the public debate about the moral and ethical dilemmas increasingly posed by scientific advances. We note the introduction of citizenship to the National Curriculum from September 2002 and suggest that which science can make a significant contribution. **What is important is not that citizens should be able to remember and recall solely a large body of scientific facts, but that they should understand how science works and how it is based on the analysis and interpretation of evidence. Crucially, citizens should be able to use their understanding of science, so that science can help rather than scare them.**

87. The need for school science to promote scientific literacy is argued in the “Beyond 2000” report, published in 1998 as the outcome from a series of seminars funded by the Nuffield Foundation.¹⁶¹ The description that it gives of what a compulsory science education for all should be aiming to achieve is shown in figure 4. The UK Deans of Science Committee tell us that “from a higher education perspective, we would happily see the general approach advocated by the Beyond 2000 report applied to the entire secondary science curriculum”.¹⁶² They also specifically emphasise “the ability to understand scientific data, including its statistical presentation” as one aspect of scientific literacy.¹⁶³ The Wellcome Trust outlined four points that they considered described scientific literacy: citizens need to be able to be engaged in informed discussion about scientific controversy; to evaluate the significance of scientific information that they may hear from different sources; to understand and interpret data giving risk and probability; and to have a basic understanding of scientific methodology and process.¹⁶⁴ In Canada, scientific literacy has been defined as “an evolving combination of the science-related attitudes, skills and knowledge students need to develop inquiry, problem-solving and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them.”¹⁶⁵

¹⁵⁷ Ev 83, para 2

¹⁵⁸ Ev 158, Appendix 29, para 5. See also Ev 88, para 2.

¹⁵⁹ Ev 155, para 11

¹⁶⁰ Ryder, J. (2001). Identifying science understanding for functional scientific literacy. *Studies in Science Education*, 36, 1-44. Zimmerman, C., Bizanz, G. L., & Bizanz, J. (1999, March 28-31, 1999). Science at the Supermarket: What's in Print, Experts' Advice, and Students' Need to Know. Paper presented at the National Association for Research in Science Teaching, Boston.

¹⁶¹ Beyond 2000: Science education for the future. 1998. Available at www.kcl.ac.uk/education. See also Ev 155, paras 7-10

¹⁶² Ev 113, Appendix 1. See also Ev 88, para 3

¹⁶³ Ev 111, para 1

¹⁶⁴ Q357

¹⁶⁵ See Annex II. See Also Ev 161, para 9; Ev 170, para 5

Figure 4: Extract from Beyond 2000: Science education for the future.

The science curriculum should:

- Sustain and develop the curiosity of young people about the natural world around them, and build up their confidence in this ability to inquire into its behaviour. It should seek to foster a sense of wonder, enthusiasm and interest in science so that young people feel confident and competent to engage with scientific and technical matters.
- Help young people acquire a broad, general understanding of the important ideas and explanatory frameworks of science, and of the procedures of scientific inquiry, which have had a major impact on our material environment and on our culture in general, so that they can:
 - ▶ Appreciate why these ideas are valued;
 - ▶ Appreciate the underlying rationale for decisions which they may wish, or be advised, to take in everyday contexts, both now and in later life
 - ▶ Be able to understand, and respond critically to, media reports of issues with a science component;
 - ▶ Feel empowered to hold and express a personal point of view on issues with a science component which enter the arena of public debate, and perhaps to become actively involved in some of these;
 - ▶ Acquire further knowledge when required, either for interest or for vocational purposes.

88. It must be recognized that there is a downside to this approach. If teachers are to have the time to teach skills associated with scientific literacy then some of the existing factual content will need to be removed from the GCSE courses. Jerry Ravetz warned that a move too far towards the teaching of cultural aspects of science could mean that “the subject becomes fluffy and loses respect”.¹⁶⁶ Ralph Levinson told us that “it has been all too easy, for example, in the general studies course, for students to write about issues without actually presenting any real knowledge of the basic science involved”.¹⁶⁷ Some students motivated by such an approach may be encouraged to take post-16 courses, but we see a risk that those who currently enjoy the knowledge based, technical nature of the science curriculum would be alienated by a course that takes a more wide ranging approach. This could be overcome by moving away from the assumption that all students will follow essentially the same science curriculum at 14 to 16. Those students interested in continuing with science post-16 would need to take additional science at key stage 4. **On balance we believe that the advantages of increasing the priority given to the teaching of skills associated with scientific literacy at GCSE far outweigh the disadvantages.**

What science do future post-16 scientists need?

89. The scientific learned societies believe that scientific literacy is a skill required by future scientists so that they appreciate “at an early stage that the rest of society will rightly take an interest in what scientists do and why they do it”.¹⁶⁸ In addition, for those continuing with science after GCSE, a wider range and greater depth of scientific knowledge and understanding, a better ability to use maths within science and more developed practical and investigative skills are needed. Some students have told us that GCSE science did not challenge them intellectually or prepare them adequately for the

¹⁶⁶ Q360

¹⁶⁷ Q373

¹⁶⁸ Ev 83, para 2

transition to A level. **It is important that students are able to follow GCSE courses that fully prepare them to continue with the academic study of science at A level.**

90. The new GCSE currently under development by QCA, described in paragraph 17, aims to reconcile the tension between preparing students for further study and for life.¹⁶⁹ The new GCSE will be piloted from 2003. This is a novel approach – changes in the curriculum and examination structure have been introduced in the past without piloting – and very welcome. Michael Terry, a teacher at Copthall School in Barnet, reflecting on the problems associated with implementing the reformed AS and A level structure, told us that “any new initiatives must be trialled and evaluated; properly funded; and with a realistic timetable for implementation”.¹⁷⁰ We agree and it appears that QCA are taking this approach to this new GCSE. On the other hand, while we recognise that change creates significant burdens for teachers, if the general consensus is that the current arrangements for GCSE science are failing students, we would like to see change starting to be introduced more quickly. This could be achieved by requiring awarding bodies to develop new ways of assessing GCSE science, as we discussed in paragraphs 73-82. **We commend QCA for taking the initiative in piloting a new approach to GCSE science which aims to reconcile the need to prepare some students for further study and to give all students the skills of scientific literacy.**

Rethinking the National Curriculum

Balanced science?

91. The National Curriculum introduced the requirement that all students study a balance of biology, physics, chemistry, earth science and astronomy to age 16. A key argument for the introduction of balanced science was that it would enable girls and boys to experience the full range of biological and physical sciences without being pressured by gender stereotypes to opt for one area or another at the age of 14. It was hoped that this would increase the demand for A level sciences and lead to equal numbers of boys and girls opting for each of the sciences post-16. This has not happened.¹⁷¹ The arguments about the benefits of balanced science for all need to be revisited.

92. On the one hand, young people have told us that they often do not have equal interest or aptitude across the sciences and would like more choice at 14. Students may be more motivated if they are able to focus on areas that interest them and drop those that do not. On the other hand, if the requirement for balanced science were removed, it could exacerbate the still existing gender divide across the sciences and further reduce the proportion of students interested in continuing with science post-16.¹⁷² Students are often not aware at age 14 of what the different sciences involve. In Scotland, where students do not follow balanced science to age 16, the gender divide is introduced in biology and physics when choices are made at age 14 and there have been significant decreases in take-up of the sciences post-16.¹⁷³ At the same time, the traditional boundaries between the various scientific disciplines are becoming increasingly blurred. Young scientists that we met at the Royal Society of Chemistry told us that they found it useful to have a grounding across all the scientific disciplines. Science-based issues faced by citizens also span the full range of the sciences and so a broad basic knowledge should enable young people to feel confident in engaging with these as they arise.

¹⁶⁹ See comments Ev 83, para 3; Ev 92, para 2.2; Ev 111, para 1; Ev 133, para 19; Ev 175, para 6

¹⁷⁰ SED 70 Unprinted evidence. See also Ev 181, para 6

¹⁷¹ See figure A4, Annex 3

¹⁷² See also Ev 114, para 2.4; Ev 144, para 16-17

¹⁷³ Ev 128, para 10; Annex 3, figure A5

93. We would like to see the balanced science approach continue at key stage 4. This does not mean that we think it necessary for students to continue to study equal amounts of biology, chemistry and physics, but that they should be taught the core principles in each of the three sciences. Beyond this core, students should be able to select areas of science in which they are interested for further study. If DfES's vision of a flexible 14 to 19 phase of education comes to fruition, students could take up other areas of science later on if they wished. **We support the balanced science approach and believe that it should continue to apply for all students. However, within this, there needs to be flexibility and scope for choice by individual students to allow them to explore areas of interest.**

How much science?

94. Since the introduction of the National Curriculum, most students aged 14-16 have spent the equivalent of one day a week, 20% of their time, studying for double science GCSE. It was hoped that the introduction of compulsory biology, physics and chemistry to 16 would, by forcing students to keep their options open, increase the numbers continuing with science post-16. In fact, the proportion of young people choosing to go on with the study of science has fallen.¹⁷⁴ The question arises whether the 20% science for all at key stage 4 has been counterproductive.

95. It can be argued that, by age 14, the interests, aptitudes and abilities of students vary widely. Students have already experienced nine years of science education. Forcing those whose interests lie in other areas of the curriculum to spend one fifth of their time on science may increase their aversion towards it. No other curriculum area is allocated this amount of time. The skills of scientific literacy and an understanding of the key principles across the sciences, which we would like all students to develop, could be taught in 10% of curriculum time at key stage 4. Those with an interest and motivation in science could choose to spend more time studying it, which would prepare them to move on to science post-16 through either traditional or vocational routes. Those students who wanted to take up additional science later on would be able to build on their core knowledge. Making decisions about science at age 14 would also promote discussion about the value of science education. Currently, these discussions are postponed until students are able to make a choice about science at age 16, by which time it is too late and many have already 'switched off' science. With less science teaching being carried out at key stage 4 it might be possible to reduce class sizes in science and reduce the pressure on teacher supply – although these are not in themselves arguments for reducing the amount of compulsory science.

96. The counterargument is that 20% science is now the accepted norm in most schools and one that science teachers have fought hard for. Science is not a single subject but three, or more, combined into one. It is therefore logical that more time should be allocated to science than other subject areas.¹⁷⁵ If students were given the choice between 10% and 20% science, there is a risk that many would choose the former, shutting off the option of continuing with sciences post-16 and leaving them ill-prepared to handle science in everyday life. This is a particular risk while there is so little flexibility and choice available to students in science from 14 to 16. To make this choice at an age when students have had limited opportunities to consider the value and relevance of science education would be unfortunate, not only for them but for the economic wellbeing of the country. There is also a danger that removing the 20% minimum would allow schools to introduce 10% as a norm, further reducing students' opportunities to study science. This may be particularly likely to occur where schools face problems recruiting science teachers or are looking to save money.

¹⁷⁴ See figure A3, Annex 3

¹⁷⁵ Ev 92, para 2.7

97. The modern foreign languages are another curriculum area which suffers from teacher shortages. The Green Paper 14-19 proposed that foreign languages could become optional at 14 to 16 in order to increase flexibility at key stage 4. This was to be balanced by the provision of languages at primary level. The Green Paper says “the majority of schools will no doubt continue to prepare students for GCSE”.¹⁷⁶ However, it has been reported that nearly 30% of schools have jumped the gun, seizing the opportunity to make languages optional from September 2002.¹⁷⁷ Of 300 students in one Sheffield secondary school, only eight are reported to have chosen to continue with French to GCSE and 16 with German. It seems that the Government is unable to intervene in such situations. It would be a tragedy if schools were to take a similar attitude to science, requiring students to take only the existing single science GCSE as a compulsory subject. We fear that this fact-driven course would send students’ engagement with science on a rapid downward spiral.

98. On balance, we are persuaded by this second argument. We believe that reducing the commitment to science at key stage 4 would be a regressive move and that 10% science would rapidly become the norm. We believe that science at key stage 4 can become an attractive and valuable experience for all students. **All students should continue to spend 20% of their time studying science. At the same time, the National Curriculum at key stage 4 must be restructured to allow the development of a range of different science GCSE courses. This should enable students to choose courses that complement their abilities and interests in science. All GCSE courses should prepare students to feel confident with the science that they are likely to encounter in everyday life and provide a route to science post-16, either through traditional A levels or through vocational qualifications.**

Curriculum content

99. The effects of an over-prescriptive curriculum were discussed in paragraph 25. Ed Walsh, a teacher at Roseland Community School, Truro told us that schools “do not try to teach the whole gamut of history or the geography of the whole world, but I think we are still hung up at key stage 4 in trying to cover all areas of science and that is a mistake”.¹⁷⁸ QCA told us that this was because “when the National Curriculum came in, what it did was merge together all the sciences into something called ‘science’, and people were very nervous about losing their own section”.¹⁷⁹ QCA felt that attitudes were now changing. This has been reflected in the evidence that we have received. Colin Osborne from the Royal Society of Chemistry said that “there are some fundamental, major ideas of science that all people need to have”.¹⁸⁰ Nigel Thomas from the Royal Society told us that “it almost does not matter what you cut out”.¹⁸¹ There was general agreement among witnesses that the topics covered should be reduced.

100. The only courses available that fulfil the National Curriculum are the single, double and triple science GCSE options. A wider range of qualifications is essential if the needs of all students are to be met. The new GCSE in Applied Science, like the foundation and intermediate GNVQs before it, is an attempt to do this. None of these courses fulfil the requirements of the current National Curriculum.¹⁸² This seems odd. Science is a

¹⁷⁶ Green Paper 14-19, paragraph 3.17.

¹⁷⁷ Times Educational Supplement. Friday 24th May. Page 1. “Schools jump the gun in ditching languages”.

¹⁷⁸ Q272

¹⁷⁹ Q464

¹⁸⁰ Q13. See also Ev 162 paras 4-5

¹⁸¹ Q13

¹⁸² This is permitted under the provisions of Section 96 of the Learning and Skills Act 2000. Further information is available from www.dfes.gov.uk/section96

compulsory subject for good reasons and the National Curriculum is there to ensure that all students receive the science education that they need. If the National Curriculum does not allow sufficient flexibility for a range of qualifications to be developed that fulfil students' needs then this is a clear message that it needs to be rewritten. We are pleased that Government has recognised this in the DfES Green Paper 14-19. It states that the National Curriculum for science is to be reviewed "to achieve a core of science relevant to all learners. This smaller programme of study could be built into a wider range of qualifications".¹⁸³ We would expect that a new National Curriculum would define only the science that all students should learn. This would incorporate key ideas from across the sciences together with knowledge and skills associated with scientific literacy. Qualifications would be built on this core, giving choice and flexibility to teachers and students to identify courses that allowed them to study aspects in more depth. **QCA should work together with stakeholders, including learned societies, teachers and students, to agree a National Curriculum that defines a minimum core of science that all students need to be taught at 14 to 16. This should include some of the key ideas in science across biology, chemistry and physics and a range of skills and understanding associated with scientific literacy. All qualifications in science offered at key stage 4 should then fulfil these revised National Curriculum requirements.**

101. The revised curriculum, which will be assessed for the first time in 2003, does include aspects of what can be described as scientific literacy. An extract is shown in figure 5. It is by no means comprehensive with, for example, no mention of risk or use of different types of evidence in science. **A new science curriculum will need to define more explicitly the skills and knowledge associated with scientific literacy.**

Figure 5: Extract from the key stage 4 National Curriculum for Science: ideas and evidence.

Pupils should be taught:

- how scientific ideas are presented, evaluated and disseminated [*for example, by publication, review by other scientists*]
- how scientific controversies can arise from different ways of interpreting empirical evidence [*for example, Darwin's theory of evolution*]
- ways in which scientific work may be affected by the contexts in which it takes place [*for example, social, historical, moral and spiritual*], and how these contexts may affect whether or not ideas are accepted
- to consider the power and limitations of science in addressing industrial, social and environmental questions, including the kinds of questions science can and cannot answer, uncertainties in scientific knowledge, and the ethical issues involved.

Putting a new curriculum into practice

Assessment

102. Paragraphs 73-82 discuss changes that are needed in the way that the current GCSEs in science are assessed. These apply equally to any new curriculum. In addition, ways of developing skills associated with scientific literacy need to be developed. The previous version of the National Curriculum, introduced in 1995, covered much of the same ground as shown in figure 5, although less explicitly. The evidence that we have received suggests that this aspect of the National Curriculum has not been given a high priority. There appear to be two main reasons for this. First, it is not examined. The Wellcome Trust tells us that

¹⁸³ DfES Green Paper 14-19, paragraph 3.11

“unless this element of the curriculum is formally assessed, teachers and students will accord [it] lower status than the examined elements and may, indeed, not cover these issues at all”.¹⁸⁴ For GCSE exams set from 2003 onwards, awarding bodies will be expected to base 5% of the marks at GCSE on the assessment of the statement in figure 5. This is progress but seems low. **Incorporating scientific literacy in the National Curriculum will not, on its own, be enough. If this aspect of the curriculum is to receive the attention that it deserves it must be given a higher priority in assessment.**

103. There is no consensus on how scientific literacy should be assessed at GCSE. Clare Matterson from the Wellcome Trust suggested that lessons should be learned from “the humanities and English that do have methods of assessing discursive ways of thinking...[we] do not have to completely re-invent the wheel”.¹⁸⁵ Ralph Levinson from the Institute of Education suggested that “an emphasis on evidence and an emphasis on argument could be one way forward”.¹⁸⁶ It is QCA’s responsibility to ensure that the awarding bodies are assessing the full breadth of the National Curriculum. **Research and development needs to be undertaken to develop ways of assessing the skills associated with scientific literacy. This should be seen as an urgent priority and funded by Government.**

Teachers

104. The second reason that the teaching of skills associated with scientific literacy has been neglected is that teachers have not been trained to do it. Teachers will need considerable support if the proposals in this report are to be put into practice. They will then be asked to teach in a different way, for which they will need training. And they will also need to plan how to teach new exam courses, which will include adjusting to new methods of assessment, developing new and interesting approaches to coursework and getting up-to-date with developments in science. This will need both time and resources.¹⁸⁷ DfES is establishing a National Centre for Excellence in Science Teaching, which will provide professional development for science teachers and technicians.¹⁸⁸ The then Schools Minister told us that the Centre would be “fully operational” within two years.¹⁸⁹ We welcome the establishment of this Centre and hope that it will have significant role in supporting the development of science teaching in schools. DfES assures us that “the timetable for introducing change will allow preparation and time for teachers to be trained”.¹⁹⁰ **If science teachers are to be asked to teach a different curriculum at key stage 4, they will need time, resources and training. The Government must ensure that all three of these are available to teachers before implementing any major changes in science at key stage 4.**

Providing for different interests

105. The interests and motivations of students vary widely. If we are to expect students to engage in science then courses must be available that will meet these different needs. This should, as a minimum, mean offering a choice between vocational and traditional courses. The development of the GCSE in Applied Science, discussed in paragraph 33, and QCA’s pilot of a new GCSE, described in paragraph 17, are the first steps in this direction. These are welcome developments but if the National Curriculum were to be revised as

¹⁸⁴ Ev 160, Appendix 29, para 18

¹⁸⁵ Q372

¹⁸⁶ Q373

¹⁸⁷ Ev 91, para 1.4; Ev 109, paras 12-13

¹⁸⁸ See also Ev 133, para 22

¹⁸⁹ Q543.

¹⁹⁰ Ev 205, Appendix 50

described in paragraphs 91-101, this would enable a much wider and more flexible range of science courses to be developed and offered at key stage 4. **QCA should work together with the awarding bodies to develop a range of courses in science at key stage 4 that reflect the diverse interests and motivations of students.**

Gender

106. A level choices show that girls and boys have not developed equal interest across the sciences pre-16, as described in paragraphs 50-52. Girls opt out of physics: boys opt out of biology. Colin Osborne of the Royal Society of Chemistry said that one of the factors was “the kind of context in which you present the curriculum. It is too easy...to go through a traditional kind of context...which would influence boys”.¹⁹¹ Michelle Ryan, a teacher at Ricards Lodge High School, Wimbledon, suggested that “girls are more interested in the application of science” giving medical physics as an example of a topic that might particularly appeal to girls.¹⁹² Ann Marks, Chair of the Women in Physics Education Sub-Group at the Institute of Physics, found in her research that girls that had studied the Salters Horners Physics and Advancing Physics A level courses (available since 1998 and 2000 respectively) were positive about their experiences of A level physics.¹⁹³ These courses were specifically designed to introduce physics through “real life” topics and we hope that they will attract an increasing proportion of girls.¹⁹⁴ We commend the Institute of Physics and the Salters and Horners Companies for funding the development of these courses. Of other syllabi, Ann Marks said “[they] do not enable girls to gain an appreciation of the excitement and relevance of physics nor do they indicate the great range of career possibilities from a physics education”. We assume that the same applies to GCSE physics.¹⁹⁵ **The evidence from A level courses that focus on presenting science in contemporary and relevant contexts suggests that it is possible to attract girls to study physics and for them to enjoy the experience. This has lessons for the study of physics at 14 to 16. QCA should explore how the curriculum and assessment at key stage 4 could be adapted to reflect the positive features seen in the new physics A level courses.**

Ethnic minorities

107. Issues around the achievement of Black students in science are discussed in paragraphs 53-56. Some positive work is going on to address these issues. The African-Caribbean Network for Science and Technology, which was set up by Black professionals in 1995 to help Black youth achieve qualifications and jobs in science, technology, medicine and engineering, has been active in bringing students into contact with Black role models.¹⁹⁶ The National RESPECT Campaign was launched in February 2002, with OST funding, to highlight the contribution of the African-Caribbean community to science, engineering and technology in the UK, and to encourage more young people from ethnic minorities into these fields.¹⁹⁷ In some areas after-school science clubs, the Ishango Science Clubs, have been established, with DfEE/DfES development funding, to provide educational support for African-Caribbean pupils, and are reported to have had a major impact on pupil achievement and motivation.¹⁹⁸ It is disappointing to hear that the future

¹⁹¹ Q39

¹⁹² Q252

¹⁹³ Ev 141

¹⁹⁴ See also Ev 104, para 134; Ev 132, para 13

¹⁹⁵ See also Ev 146, para 25

¹⁹⁶ SED14. Unprinted evidence. See also Ev 147, appendix 27

¹⁹⁷ *Ibid*, paras 4.29-4.33 Unprinted evidence

¹⁹⁸ *Ibid*, paras 4.2-4.18. Unprinted evidence See also Ev 154

of these clubs is threatened by lack of continuing local funding.¹⁹⁹ **We recommend that the Government consider how best to ensure the future of the Ishango after-school Science Clubs, if necessary by continued central government funding.**

108. The African-Caribbean Network for Science and Technology recommends that the Government commission further research on race equality in science, maths and technology and explore ways of targeting resources on underachieving groups. It calls for science teaching materials to be developed to encourage multi-cultural and anti-racist teaching; and for teaching training and continuous professional development for science teachers to include these elements. We endorse these recommendations.

Specialist schools

109. Some schools have chosen to become “specialist schools”, emphasising a particular curriculum area, although they must continue to teach the full National Curriculum. The initiative was launched in 1994 and, from September 2002, there will be 834 specialist schools. Of these, 409 will be Technology Colleges, 143 Arts Colleges, 141 Language Colleges and 141 Sports Colleges.²⁰⁰ The first applications for the new specialist categories of Science, Engineering, Maths and Computing and Business and Enterprise were submitted in March 2002. 38 schools applied for science specialist status and seven for engineering status. Huish Episcopi Community School, Somerset and The King John School, Essex, which were visited by members of the Committee in the course of the inquiry, have recently been awarded science, and maths and computing, specialist status respectively. The Government’s target is for 1,500 secondary schools in England (roughly 50%) to have specialist status by 2005. A similar approach has been taken in Japan, where 26 schools are to be designated “Super Science High Schools”.²⁰¹ This is part of a wider “Science Literacy Enhancement Initiative”, where £31 million has been allocated over two years to science education.

110. Ruth Wright from the Engineering Council told us that, initially, they were not enthusiastic about the idea of engineering schools because they “thought it was probably some way of going for a two-tier or three-tier education [system]”.²⁰² These fears had been allayed following discussions with DfES, although the Engineering Council saw similar concerns from schools as the likely explanation for the low number of applicants for the engineering specialism. They predicted that the numbers will grow “once exemplar high-flying Engineering Colleges are up and running”.²⁰³ Stephen Timms, the then DfES Schools Minister told us that “the first benefit I expect [from specialist schools] is an improvement in standards. Secondly... I will expect the establishment of science specialist schools to be able to strengthen the provision of science in some primary and secondary schools in the area where the school is located”.²⁰⁴ Richard Shearman of the Engineering Council told us that “if specialist schools can be used to create good practice in the teaching of science and technology...that could well provide useful material for the education system as a whole”.²⁰⁵ Science specialist schools could lead the way in piloting new approaches to the 14 to 16 curriculum.

111. There could, on the surface, appear to be some duplication between the new specialisms and the Technology Colleges, which have to focus on two curriculum areas

¹⁹⁹ *Ibid*, para 4.18. Unprinted evidence

²⁰⁰ DfES Press notice 2002/0015, 5 February 2002. Available via www.dfes.gov.uk.

²⁰¹ SED103. Unprinted evidence

²⁰² Q63

²⁰³ Register news no. 4 - formation - 3-19 education. Engineering Council. April 2002. Available via www.engc.org.uk

²⁰⁴ Q530

²⁰⁵ Q63

chosen from science, maths, design and technology and ICT. In practice, it seems that many Technology Colleges have focused on the use of ICT within school, investing most of the additional funds associated with specialist status in purchasing hardware. **We welcome the establishment of science and engineering specialist schools as a recognition that Technology Colleges, although numerous, are not representing the breadth of science and technology education. The Government should set a target for the number of science and engineering specialist schools within the overall target of 1,500 specialist schools by 2005.**

112. All applicants for specialist status have to raise £50,000 in sponsorship, a significant barrier for some. Advice and support in raising sponsorship is available for schools through the Technology Colleges Trust, which manages the specialist schools programme on DfES's behalf.²⁰⁶ Separately, a consortium of engineering bodies came together to provide the sponsorship needed for three schools to apply for engineering specialist status.²⁰⁷ We welcome this move and would like to encourage scientific bodies to work together to support schools in a similar way. This could be by offering funds themselves, as in the case of the engineering bodies, or by working with potential sponsors from business and industry. **We urge scientific bodies to consider how they can encourage and support schools to apply for science specialist status.**

²⁰⁶ See www.tctrust.org.uk

²⁰⁷ The consortium comprised EEF (Engineering Employers' Federation), EMTA (the National Training Organisation for Engineering and Manufacture), MTTA (the Machine Tool Technologies Association), the Engineering Council, the Engineering Development Trust and the Royal Academy of Engineering.

POST-16: THE WAY AHEAD

113. The major challenge for science post-16 is to attract students while ensuring that the courses offered provide a sound basis for further study in science. This requires A level courses which do not appear discouragingly difficult and boring, alternative science courses linked more clearly to careers and better information for students.

A levels

Content

114. The Roberts Review found that the average A level point score of undergraduates in scientific disciplines had increased in recent years.²⁰⁸ This needs to be reconciled with universities' perceptions that the quality of their intake is falling.²⁰⁹ This is at least partly caused by the increasingly varied background of undergraduate students and the provision of A level courses that offer flexibility and prioritise contemporary science. We think that these changes in the style of A level science should serve to motivate and interest students and that universities are best served by enthusiastic students who want to learn. If A level courses were designed primarily so that they provided a stepping stone to go on to university, there would be a risk that an increasing number of students would opt out. Post-16 students at Quintin Kynaston School in London told us that they had already been put off studying science at university by comments from older friends that had moved on to higher education. They would be switched off even earlier if A level courses took the same approach.

115. 60% of A level students take at least one science or maths subject. They will go on to a wide range of employment and higher education courses. David Giachardi of the Royal Society of Chemistry has told us that “chemistry is very interesting for its own sake and if somebody, for example, reads a chemistry degree...and goes off into the City, is that a waste?”²¹⁰ The same applies to A level sciences. The reality is that many students only choose science A levels if they think that they will need them for their career. We would like to see students encouraged to study science A levels as part of a broad education and see no reason why science A levels should be specifically orientated to the needs of science and engineering departments at universities.²¹¹ **In providing A level science courses it is difficult to strike a balance between attracting a broad range of students and providing the content needed for transition to science-based courses at university. The onus should be on universities to adapt to the changing nature of their intake. The Roberts Review recommends that the Government fund universities to use new “entry support courses” and e-learning programmes to bridge gaps between A levels and degree courses. We endorse this recommendation.**

Maths skills

116. Claire Dawe, a student at Redland High School, Bristol told us about how her school was approaching the issue of mathematical skills: “We have one lesson of maths a week which basically goes over all the maths which will be needed within our science syllabus, so it keeps up the maths skills. I think that is a very good idea”.²¹² This approach

²⁰⁸ Roberts Review, para 3.12

²⁰⁹ See paragraphs 66-68 above

²¹⁰ Evidence taken for the Inquiry into Scientific Learned Societies. Q210.

²¹¹ See also Ev 114, para 2.2; Ev 132, para 15

²¹² Q106

has been formalised in courses developed with funding from the Nuffield Foundation.²¹³ For example, an AS in the Use of Mathematics has been developed which is specifically designed to teach maths in ways that support other subjects. A similar solution is now used at Nottingham Medical School with the introduction of a data analysis module to reinforce mathematical skills.²¹⁴ Again, it is necessary to strike a balance between providing courses that attract students to A level science while also providing a basis for transition to university. The Institute of Physics published a report on undergraduate physics in 2001, which concluded that university physics departments needed to alter their courses in response to changes at A level and to give students opportunities to strengthen their maths skills.²¹⁵ It also argued that there was a case for a new type of physics degree with less mathematical content that would be part of a general education rather than preparation to become a physicist. **On balance we are persuaded that the mathematical demands of school science at A level are appropriate. Where students need support with their maths, additional maths courses are available for schools to offer. Any increase in the maths content of A level science courses would risk alienating students further. Where universities require greater mathematical skills, they should take action to teach these themselves.**

Difficulty

117. It seems that it may be more difficult to achieve high grades in A level science subjects than some others. There are several ways of looking at this. One is to accept that science by its very nature – requiring students to understand abstract concepts and develop a particular way of thinking and processing information – is, and always has been, more difficult than some other subjects. If young people find the subject interesting, see its relevance to their lives and are fully aware of the value of scientific qualifications for future careers, they will choose to study science for these reasons. The challenge is to achieve this, which is discussed elsewhere in this report. A second is to aim to make grades across all A level subjects comparable. The Roberts Review believed that “this can and should be done without compromising the core knowledge and skills needed for studying science and engineering in higher education”. A third is for universities to give a greater weighting to grades in those subjects that are known to be more difficult. This may occur already to some extent. Students do not want to get lower grades than their peers and are deterred from taking science simply out of interest. **The Government should ask QCA and the awarding bodies to explore how it would be possible to address the imbalance in grading across A level subjects.**

Alternatives to A level

118. Vocational courses in ‘science’ have not attracted a large number of students, as described in paragraphs 64-65. FE colleges offer vocational courses that are linked directly to specific careers; schools do not usually have the equipment or expertise to deliver these courses. Chris Roberts from Bradford FE College gave us examples of science-based vocational courses offered by his college, which included pharmacy, ophthalmic dispensing and sports science.²¹⁶ Students studying beauty therapy at Hammersmith and West London College told us that they had not initially realised that the course would include any science, but that having studied aspects of science as part of their course, they had enjoyed it. Their course would have included aspects of microbiology, dermatology, anatomy, physiology, nutrition. Their lecturers suggested that if the students had been taught these topics as

²¹³ Ev 157, paras 23-24

²¹⁴ Q388. See also Ev 89, para 11.

²¹⁵ Physics - building a flourishing future. Institute of Physics. 2001. Available via www.iop.org

²¹⁶ Q312

straight science rather than in the context of beauty therapy, they would not have enjoyed it. Jane Clifford, a lecturer at Brooklands College in Surrey, pointed out that many of the students entering FE colleges would have struggled with GCSE science. She said that they “very often feel that science is hard and it is not a subject that they want to do”.²¹⁷ Rather than retaking GCSE science, and potentially failing again, they would be encouraged to take vocational courses where the different style of learning could enable them to succeed. **FE colleges offer a range of science-based vocational courses linked to specific careers. These give students the opportunity to engage with science and achieve where they may previously have struggled.**

119. The vocational qualifications in science do have an important role in allowing students who have not achieved on traditional courses to engage with science and move on to further or higher education in science or employment. The Association of Colleges tell us that the Intermediate GNVQ is a useful stepping stone between GCSE and VCE. Without it, students who do not achieve at GCSE will have limited options available.²¹⁸ They are concerned that QCA plan to terminate the intermediate GNVQ in 2006 in the expectation that the Applied Science GCSE will be fulfilling the same role, which they did not think it would do. This can be contrasted with the situation in Scotland where there are now five different levels of qualification available to students after they have completed Standard Grade, the equivalent of GCSE. Teachers that we spoke to at Beeslack High School, Penicuik told us that students were motivated by the knowledge that there was a course in science that they could progress to even when they had not achieved top grades at Standard Grade. **For those students who do not achieve grade C in GCSE science, there need to be intermediate qualifications available that will allow them to move on to AS and A level or VCE.**

A broad education

120. In paragraph 85, we say that students should be required to have studied a balance of biology, chemistry and physics in order to be awarded a matriculation diploma at age 19. To go one step further, the question arises whether science should be a compulsory subject for all post-16 students as part of a broad education. We note that the International Baccalaureate, offered by some schools in England, requires students to study a science to age 18.²¹⁹ In France, all students studying academic courses leading to the baccalaureate study a core science curriculum. In Germany, students must continue to study at least one science to age 19. In Canada, to qualify for a university course, even to read arts, a specific science course (biology, chemistry, physics or earth sciences) needs to be taken post-16. In Sweden, a Science Studies course forms part of all national programmes available to post-16 students – not just those following academic courses, but vocational too. This course “aims to provide the knowledge of science necessary for people to engage with it as citizens”. In the other countries from whom we received evidence (Denmark, Iceland, Italy, Holland, Switzerland, the United States and Japan), we understand that science is not compulsory post-16.²²⁰

121. The introduction of a post-16 curriculum in England that laid down compulsory subjects would represent a major shift in approach.²²¹ This is particularly true now that a wider range of courses, including vocational and work-based options, are followed by post-16 students. Schools and colleges are still adapting to the recent post-16 reforms, which were intended to broaden the range of subjects studied by students. As noted in paragraph

²¹⁷ Q313

²¹⁸ Ev 103, para 123. GNVQs will continue to be accredited until 2006.

²¹⁹ Q260

²²⁰ See Annex 2

²²¹ See proposals Ev 108, paras 7-10; Ev 139, paras 3.7-3.8; Ev 164, para 36

47, it does not seem that these reforms have resulted in a significant increase in the number of students studying science to AS level post-16. **In evaluating the new AS and A level structure, the Government should look closely at whether the changes have successfully broadened the curriculum studied by post-16 students. If this is not the case, Government should consider the introduction of a compulsory post-16 curriculum, which would include science as one of its core subjects.**

Increasing the awareness of scientific careers

122. As we have seen, students tend to choose to study science post-16 despite their experiences at GCSE rather than because of their experiences. They are motivated by longer term ambitions, although students knowledge of the options open to them after studying science is limited. **Improving the experience of science at 14 to 16 in the ways that we suggest in this report should motivate students to consider studying science post-16. They should be provided with proper careers advice.²²² Government should ensure that the careers service improves the quality of advice offered to school students about scientific careers and the breadth of career possibilities open to those with qualifications in science.**

123. Young people have reported that careers advice is most helpful where they already have an idea of the area in which they would like to work, so their initial interest in science related careers needs to be stimulated in other ways. A student at Quintin Kynaston School, London told us that his knowledge of where scientific careers could lead came from his mother, a virologist. Most students do not have such inspiration available to them so close to home and this is where it can be useful to identify role models. Nigel Thomas of the Royal Society told us that the best way to increase the number of girls interested in scientific careers would be to “put women as role models in the situation where they were accessible to school pupils”.²²³ We would see the same applying to boys. There are a number of schemes that create opportunities for students to meet scientists. Sheffield Hallam University tell us about their Researchers in Residence programme, run with funding from the research councils.²²⁴ It is based on postgraduate students spending between six and eight half days in a school, working with students on science investigations and projects. Government has recognised the value of role models in motivating young people, which resulted in the launch of the Science and Engineering Ambassadors scheme in January 2002 as a joint initiative between DfES and DTI. This aims to bring 30,000 young people working in science, engineering and technology into schools for a few days each year to act as role models and mentors. Their role is to work with teachers rather than as teachers and this we support. Teaching is a profession; scientists are not trained to do it. **We welcome the motivation behind the Government’s Science and Engineering Ambassadors initiative and look forward to seeing an evaluation of how effectively it is implemented and what impact it has.**

124. Research by the National Institute for Careers Education and Counselling (NICEC) reports that work experience is commonly cited as the most useful part of a careers programme. Most young people have the opportunity to go on work experience placements, usually for one or two weeks. However, the NICEC research found that schools often had difficulty finding placements in science and engineering based employers because of insurance and health and safety issues or the lack of local science-based employers.²²⁵ Teachers in Bolton said that science students often carried out work

²²² Ev 145, para 21-22; Ev 174, para 20

²²³ Q39

²²⁴ SED26. Unprinted evidence. See also Ev 131, para 4

²²⁵ SED6. Unprinted evidence. Choosing Science at 16: The influences of science teachers and careers advisers on students’ decisions about science subjects and science and technology careers. 2000. Published by CRAC.

experience in completely irrelevant environments, for example working as shop assistants.²²⁶ They wanted engineering and science-based companies to be encouraged to participate in work experience schemes. NICEC suggest that alternative approaches, such as work shadowing, work simulation or short courses, be explored by schools and employers. One example of this is a three day event for girls run by the Women into Science and Engineering scheme, described to us by George Salmon of the Institution of Incorporated Engineers.²²⁷ Over the three days the students visit several local engineering companies and complete an engineering project. Victor Lucas from the Engineering Council told us that a number of similar schemes exist but that the level to which schools and colleges get involved “is very variable across the country”.²²⁸ We have heard from Denmark of a pilot project in which students, as part of a three year post-16 science course, spend one week each year carrying out a science-based project in a local company.²²⁹

125. An increase in the teaching of vocationally orientated courses at 14 to 16 might change this. For example, the new GCSE in Applied Science will require students to complete a project investigating how science is used in selected workplace. The AQA draft specification for this course suggests students could look at a hospital laboratory, a civil engineering company or an environmental monitoring consultancy, among others. This sort of project has the potential to bring science to life for young people studying traditional science courses as well. However, it is time consuming for teachers to organise outside visits or speakers and it also uses valuable classroom time. Where teachers feel under pressure, whether from their workload or from an overloaded curriculum, they are less likely to use time setting up links with local companies. **A benefit of requiring science to be taught using contemporary contexts is that it would encourage more science teachers to make use of local science-based employers to support their teaching.**

²²⁶ Ev 201. See also Ev 146, para 27-29

²²⁷ Q69. See also Ev 173, Exhibit 2

²²⁸ Q69

²²⁹ Annex 2

RESOURCES FOR PRACTICAL SCIENCE

Laboratories

126. In most schools all science lessons are taught in laboratories, allowing teachers to introduce practical work flexibly as and when they wish. The Royal Society estimate that, on average, a secondary school would have six laboratories.²³⁰ This could mean two for each of biology, chemistry and physics but, as most schools will aim to allocate each teacher their own laboratory, many of whom will teach more than one scientific discipline, there may only be dedicated subject laboratories for post-16 sciences. Schools often store basic equipment such as bunsen burners in each laboratory but most equipment is likely to be kept in a separate “prep room”. The prep room is also where technicians work, preparing materials for teachers to use in their practical lessons.

127. Good laboratory and prep room facilities are important because they enable high quality practical work to be carried out in a pleasant environment, motivating and inspiring staff and students alike. In 1999 Ofsted estimated that the science accommodation in 20% of secondary schools, some 750 schools, was of such poor quality that teaching was being affected directly.²³¹ Since then, the figure has risen to 26% – some 905 secondary schools.²³² **It is appalling that the laboratories in one quarter of England’s secondary schools are in such a poor state that the quality of teaching is being directly affected.**

128. DfES responded to Ofsted’s 1999 report by committing £60 million over the two financial years 2000/01 and 2001/02 to laboratory refurbishment and rebuilding.²³³ The funds were allocated to LEAs to spend with their schools as appropriate; LEAs have until the end of August 2002 to spend their allocations. Stephen Timms, the then DfES Schools Minister, told us that the money was expected to reach 400 of the then estimated 750 schools with unsatisfactory science accommodation.²³⁴ Both the Royal Society and the Royal Society of Chemistry estimate that modest refurbishment, including the supply of new furniture, would cost a minimum of £20,000 per laboratory. Refurbishment of a prep room would cost a minimum of £13,000.²³⁵ If the £60 million was distributed evenly to 400 schools each with six laboratories and one prep room (which is unlikely, of course), this would have allowed £23,000 for the refurbishment of each laboratory and £13,000 for the prep room – sufficient to make a significant impact. Frome College in Somerset, which was visited in the course of this inquiry, has recently opened new science labs. The Royal Society has carried out a survey which tells us of “teachers and pupils being overjoyed and genuinely enthused by the modern and bright appearance of their new labs” in those schools that had benefited from the additional funds.²³⁶ Government has not carried out an evaluation of its own. DfES tell us that “the precise format of the evaluation is yet to be finalised, and we anticipate the report will be completed by next summer”.²³⁷ We find it astonishing that, more than two years after announcing the investment of a significant sum of public money in school laboratories, DfES has not even decided how to evaluate the impact of these additional funds. We fail to see how DfES can make informed decisions about what further investment is needed without such evaluation. **We welcome the £60 million committed to laboratory refurbishment by DfES; this should have made a**

²³⁰ Science teaching resources: 11-16 year olds. Royal Society. 1997.

²³¹ Ofsted Annual report 1997/98, published February 1999.

²³² Data from Ofsted reported in the Roberts Review, figure 2.18

²³³ DfES press notice 2000/0171, April 18, 2000. Available via www.dfes.gov.uk

²³⁴ Q521

²³⁵ Ev 86, para 6 and ev 87, Appendix 4. Upper estimates of cost laboratory refurbishment range from £55,000-£70,000, which would include building work to remodel or renew services such as gas, electricity, water and drainage.

²³⁶ Ev 86, para 3.

²³⁷ Ev 205, Appendix 50

significant impact. We are very surprised that DfES has not evaluated what impact this substantial sum of public money has had on those schools most in need.

129. The £60 million committed by DfES was only ever expected to meet half the need. On the basis of their survey, the Royal Society estimate that additional funds of between £60 million and £120 million are required to bring all school laboratories in England up to an adequate standard. Taking Ofsted's most recent estimate of 905 schools with science accommodation so poor that it is affecting teaching, the amount needed is nearer £120 million.²³⁸ Considerably more investment would be needed to bring all school laboratories up to a good or very good standard.

130. It is not the intention of DfES to provide another tranche of money specifically for laboratories. Mr Timms told us that in 2002-03 there would be approaching £3 billion available for capital investment in schools. He said "we are moving...towards giving schools the decision about where that capital should be invested, and away from ring-fencing; so I do not envisage another initiative like the £60 million initiative".²³⁹ We recognise that the quality of school laboratories varies widely and some schools do have excellent facilities and will want to focus resources in other areas.²⁴⁰ We also agree that in general it is best to give schools the freedom to decide their own priorities. However, we are concerned that in those schools with poor facilities, the costs associated with laboratory refurbishment are so high that schools will be reluctant to place this as a high priority. Additional funding would need to be targeted at these schools. We would not want to see a bureaucratic arrangement introduced where schools would have to bid for funds. DfES's decision to allocate the initial £60 million investment in laboratories to LEAs, who could then target the funding at those schools most in need, seems to us the most sensible way of allocating further funds. Once all schools have appropriate facilities for teaching science, funding for ongoing maintenance and refurbishment should not need to be ringfenced. **We recommend that, over the next three years, the Government ringfence a minimum of £120 million to bring all school laboratories and prep rooms up to at least adequate standard. This money should be allocated direct to LEAs so that it can be targeted at those schools most in need.**

Equipment and consumables

131. Some teachers have told us that their practical work is limited by the availability of consumable resources such as chemicals. Even more significant is the need to replace large and expensive pieces of equipment, such as microscopes and centrifuges, many of which are now reaching the end of their useful life.²⁴¹ These items can be very costly to replace. The Royal Society carried out a detailed study in 1997 which, by allocating a cost and lifespan to each piece of equipment needed for teaching national curriculum science, calculated the cost per student per year.²⁴² In 1997, they estimated that schools were underspending by about £2 per student per year and they believe that this is still likely to be the case now. They now estimate that schools in England need to spend an additional £6 million each year if their laboratories are to remain adequately stocked with functioning equipment and resources required to teach national curriculum science.²⁴³ While we are persuaded that funding for capital investment in science should be ringfenced, we do not believe that this is practical, or desirable, for revenue funding in science. Schools should retain the autonomy over the allocation of their resources but should be provided with

²³⁸ Refurbishing 6 laboratories at £20,000 each and one prep room at £13,000 in 905 schools would cost £121 million.

²³⁹ Q521

²⁴⁰ Q44

²⁴¹ Q237

²⁴² Science Teaching Resources: 11-16 year olds. Published by the Royal Society, October 1997.

²⁴³ Ev 86, para 9. See also Ev 182, Appendix 40

information on which to base their decisions on funding for science departments. It would be helpful if the Royal Society were to update their 1997 publication “Science teaching resources: 11-16 year olds”. This would provide invaluable guidance for schools on the costs associated with equipping their science department. **DfES should ensure that schools are properly informed of the importance and costs of maintaining expenditure on science equipment.**

Technicians

132. Technicians are non-teaching staff, employed by schools primarily to support practical work. This is likely to include preparing equipment and solutions for use in lessons, stock control, maintenance of equipment and health and safety. Some technicians support practical lessons in the classroom. Like all other non-teaching staff, pay scales are determined by local authorities; the school decides where on the pay scale each post should lie. The Royal Society and the Association for Science Education recently published a report on the action required to strengthen technician support in schools and colleges.²⁴⁴ This report concludes that technicians have a vital role to play in the provision of high quality science education but that the number of technicians employed by schools and colleges is inadequate. The report estimates that schools and colleges in England need to create an additional 4,000 science technician posts in order to provide adequate technical support to all science departments.

133. Nigel Thomas of the Royal Society told us that “you would see a dramatic rise in the standard, say, of practical work if there was a vital investment in the support structure, in technicians”.²⁴⁵ Gillian Halton, a technician at the Institute of Education at Manchester Metropolitan University, reinforced this view: “If you are going to do good quality practical work then a good quality technician is vital”.²⁴⁶ She pointed out that technicians provide important support both for teachers and students. We have been told that the biggest problem for technicians in schools and colleges “is the lack of technician resource”.²⁴⁷ Chris Peel, a technician at City and Islington Sixth Form College said that this was because “schools historically do not employ enough [technicians] for the science curriculum they offer”.²⁴⁸ Catherine Crocker, a technician at Esher Sixth Form College, told us that they were having problems recruiting technicians when vacancies arose because “it is not a very attractive career”.²⁴⁹ Pay is low; we are told that salaries average £9,000, many technicians are paid during the term time only and typically work 30 hours per week.²⁵⁰ There is no career structure and the RS/ASE report found that “many [technicians] were disillusioned because of their inability to progress as they gained experience and qualifications”. Catherine Crocker told us that a senior technician earns little more than a trainee technician.²⁵¹

134. There are few training opportunities for technicians. This is partly because courses are not available at convenient locations or times and partly because funding is not available.²⁵² Technicians in Bolton reported that, although NVQ courses were available through local colleges, they could not attend because they were only run during the day.²⁵³ Further, there is little motivation to undertake training when it will not be linked to career

²⁴⁴ Supporting success: science technicians in school and colleges. 2002. Available via www.royalsoc.ac.uk/education

²⁴⁵ Q22

²⁴⁶ Q281

²⁴⁷ Q283

²⁴⁸ Q285

²⁴⁹ Q283

²⁵⁰ Q286

²⁵¹ Q283

²⁵² Q308

²⁵³ SED 96 Ev 201

progression. Under these circumstances it is no surprise that Chris Peel, a technician at City and Islington Sixth Form College, told us that it is difficult to “promote the idea of being a technician as a professional occupation; it is more of a stopgap job”.²⁵⁴

135. The pay and conditions under which technicians are employed strike us as downright exploitation. We can see no reason why technicians should be paid during the term time only. Those technicians who prefer not to work during the holidays, carrying out essential tasks such as equipment maintenance, should be employed on part-time contracts; others should be treated like teachers and paid an annual full-time salary. The lack of opportunities for career or pay progression needs to be addressed. We welcome the report from the Royal Society and the Association for Science Education and compliment them on raising the profile of these issues. We recognise that similar issues are likely to apply to other support staff throughout schools and that there may be significant resources implications if these are to properly addressed. We are pleased that the DfES is in dialogue with the Royal Society and the Association for Science Education to discuss the recommendations of their report on science technicians.²⁵⁵ **We expect to see action taken within the next year to address the appalling pay and conditions of science technicians and to create a career structure that will attract skilled and dedicated people to work as technicians.**

136. Unless technicians are given the opportunity to develop their skills, they will not be able to provide teachers and students with the level of support that they need to carry out high quality practical work. DfES are in the process of establishing a National Centre for Excellence in Science Teaching. We are pleased that DfES have proposed that this Centre should provide support for technicians as well as teachers.²⁵⁶ **It is essential that technicians have opportunities for professional development. This will mean not only making appropriate courses available but also ensuring that technicians have the time and funding to be able to participate.**

Health and safety

137. **There is a widely held belief that practical work in schools is now constrained by health and safety regulations. This is simply not true.** Indeed, we have heard that the introduction of risk assessment as standard practice enables a wider range of experimental work to be carried out than previously.²⁵⁷ Advice on health and safety is available to schools from the CLEAPSS School Science Service and the Association for Science Education (ASE).²⁵⁸ However, it may well be the case that some teachers believe inaccurately that certain experiments are banned. It has also been suggested to us that supposed regulations may be used as an excuse by teachers not to do practical work where other health and safety issues are the real concern. This may apply in particular where teachers lack confidence when teaching outside their scientific discipline, where there is a lack of technical support or where classes are too large.²⁵⁹

²⁵⁴ Q285

²⁵⁵ Ev 125, para 45

²⁵⁶ Q523

²⁵⁷ Q295. See also Ev 93, para 7.2; Ev 165, paras 47; Ev 183

²⁵⁸ See www.cleapss.org.uk and www.ase.org.uk. CLEAPSS is the Consortium of Local Education Authorities for the Provision of Science Services. See Ev 182, Appendix 40

²⁵⁹ Q20

Class size

138. The scientific learned societies and the ASE highlighted large class sizes in secondary science as making it difficult for teachers to manage practical classes.²⁶⁰ James Salmon from the Anglo-European School, Essex described teaching classes of “30-32 [students] in labs that were designed for 24”.²⁶¹ Catherine Crocker said that “if there are 30 pupils most teachers would like to have somebody else in there in practicals, but it does not happen”.²⁶² Data provided by Ofsted, based on inspections carried out in the 2000/01 academic year, shows class sizes in double science GCSE ranging from 6 to 34 students, with a median of 24. A small survey carried out by the ASE suggest that it is the top sets in science that tend to be larger so that it is the most able students who are being most directly affected.²⁶³ In contrast, legislation limits practical science lessons to 20 students in Scottish schools and to 24 in Northern Ireland.²⁶⁴ The ASE do not believe that it is currently possible to impose a size limit in England. We recognise the difficulty of implementing smaller class sizes in science given the existing teacher shortage but feel that, in the interests of health and safety, this should be a priority. **The longer term aim should be to reduce secondary school practical science classes to no more than 20 students.**

²⁶⁰ Ev 93, para 7.4 and Ev 84, para 9. See also Ev 181, para 13

²⁶¹ Q242

²⁶² Q303

²⁶³ Ev 93, para 7.4

²⁶⁴ The Schools Scotland Code 1956, regulation 15(2), specifies a maximum of 20 students in a class for “practical instruction in science, art, art crafts, mechanics, benchwork, technical drawing, typewriting, cookery, laundry-work, dressmaking, housewifery, agriculture, gardening, dairying, navigation and seamanship”. The Secondary Schools (Grant Conditions) Regulations (Northern Ireland) 1973, regulation 15, specifies that practical classes should be restricted to 20 students unless the Department of Education approves otherwise. Subsequently, circular 2001/14, issued in 2001 by the Department of Education, gave blanket approval for science classes to be increased to 26 students at key stage 3 and 24 at key stage 4.

CONCLUSION

139. We have found that there are major problems in science education in schools, notably at GCSE. These are problems with the curriculum and, worse, with the system of assessment. Teachers and students are frustrated by the lack of flexibility. There is general agreement about what is wrong, but insufficient urgency in addressing the problem. The Government's plans to revise the National Curriculum and to support the pilot of a new style GCSE are welcome, but not enough. The Government should set down a clear timetable for change and assume responsibility for ensuring that it is achieved. The awarding bodies will need to be pushed into action. The Government should ensure that the problems identified in this report are tackled and show that it takes science education seriously by providing funding for decent laboratory facilities and technician support.

140. We shall seek an opportunity to debate this report. **We suggest the following motion for debate by the House:**

“That this House takes note of the conclusions and recommendations in the Third Report of the Science and Technology Committee on Science Education from 14 to 19 (HC 508-I); notes the concerns reflected in that Report about the failure of GCSE science to prepare students effectively either for further study or for citizenship; accepts the need to revise the curriculum and reform assessment so that teachers have the flexibility to respond to students' interests; acknowledges the work that has been done to develop new and innovative courses for both GCSE and AS and A level; recognises the vital role of practical work within science education and notes the poor quality of laboratories and the shortage of skilled technicians within many schools; and calls on Government to give urgent priority and sufficient funds to address these issues”.

LIST OF RECOMMENDATIONS AND CONCLUSIONS

The GCSE curriculum

1. It is clear that the major problems lie at key stage 4. ... Many students lose any feelings of enthusiasm that they once had for science. All too often they study science because they have to but neither enjoy nor engage with the subject. And they develop a negative image of science which may last for life (paragraph 24).
2. The GCSE science curriculum is over-prescriptive. This puts students off science because they do not have the flexibility to explore areas which interest them. It kills the interest in science which may have been kindled at primary school (paragraph 25).
3. If students are to be able to see the relevance of their school science, the curriculum should include recent scientific developments (paragraph 27).
4. Students want the opportunity to discuss controversial and ethical issues in their science lessons, but this happens very rarely. Engaging in debate is an approach to teaching that is unfamiliar to many traditional science teachers; and the way that science is assessed means that students are not rewarded for thinking for themselves or for contributing their own ideas (paragraph 28).
5. During GCSE students repeat much of the science that they have covered in key stage 3. Inevitably they find this boring (paragraph 29).

Practical and fieldwork

6. The science curriculum at 14 to 16 aims to engage all students with science as a preparation for life. At the same time it aims to inspire and prepare some pupils to continue with science post-16. In practice it does neither of these well (paragraph 32).
7. We endorse the view of the Field Studies Council that fieldwork should be strongly recommended in all courses (paragraph 35).
8. In our view, practical work, including fieldwork, is a vital part of science education. It helps students to develop their understanding of science, appreciate that science is based on evidence and acquire hands-on skills that are essential if students are to progress in science. Students should be given the opportunity to do exciting and varied experimental and investigative work (paragraph 40).

Coursework

9. The way in which coursework is assessed for GCSE science has little educational value and has turned practical work into a tedious and dull activity for both students and teachers (paragraph 41).

Use of ICT

10. ICT may have the potential to revolutionise science teaching but the evidence would suggest that it has not yet had a real impact in many schools (paragraph 42).
11. There needs to be a clearly defined role for ICT within science teaching if it is to have any real educational value (paragraph 43).

Take-up post-16

12. It would seem that students study science post-16 not because of science at GCSE but despite it (paragraph 44).
13. It seems that recent reforms to post-16 education have not produced a significant increase in the number of students studying sciences (paragraph 47).

Gender

14. We welcome the increase in the number of girls studying biology and chemistry to A level that has occurred since the introduction of compulsory balanced science to GCSE. In particular we are pleased that girls now make up 50% of A level chemistry entries. We are, however, concerned that physics remains an unpopular option with girls (paragraph 50).
15. The falling number of boys choosing biology and chemistry A level is a matter for concern. The reasons for this need to be investigated further and we recommend that DfES fund research in this area (paragraph 51).
16. The GCSE science curriculum fails to provide for the differing interests of boys and girls (paragraph 52).

Ethnicity

17. We welcome the introduction of pupil level ethnic monitoring by DfES. We trust that the data will show the performance of different ethnic groups in science subjects and recommend that this information will be made public as part of DfES's annual statistics publications (paragraph 54).
18. It would appear that some of the usual assumptions about the relative participation of men and women in science and engineering are simply not true in respect of ethnic minority students (paragraph 55).

Student perceptions

19. Students may be dissuaded from studying science at A level if they think it will be harder work than other subjects and more difficult to achieve a high level grade (paragraph 57).
20. The mathematical requirements, or students' perceptions of the mathematical requirements, of A level sciences puts students off choosing to study these subjects. This particularly applies to physics (paragraph 59).

- 21. Students' awareness of scientific careers and the value of transferable skills gained through science would appear to be limited (paragraph 63).**

Vocational pathways

- 22. The vocational options in science are not yet attracting students. More should be done to provide attractive vocational courses and to ensure that students are well aware of the potential value of the qualifications for a range of future careers (paragraph 65).**

Universities' demands

- 23. Where universities place restrictive demands on applicants, specifying grades in three A level subjects, students are unlikely to place value on broadening their education (paragraph 68).**

Responsibility

- 24. We are amazed that the awarding bodies take so little responsibility for finding solutions to problems with GCSE science that they themselves have caused. We take little comfort from their ability to identify these problems when they show little initiative in addressing them. Government should make plain to the awarding bodies that the future accreditation of their science GCSE courses depends on them developing imaginative alternative ways of assessing science at GCSE. Any changes to the National Curriculum will have limited impact on the way science is taught in schools if the assessment is not changed too (paragraph 71).**
- 25. QCA's lack of direction has allowed assessment of GCSE science to stagnate. QCA should now set out clearly what they expect of awarding bodies offering science GCSEs and should intervene where these criteria are not met (paragraph 72).**
- 26. QCA should require awarding bodies to introduce a wider range of questions to GCSE science exams. These should enable issues raised by contemporary science to be used as the focus for questions; allow flexibility for students in their answers; and, most importantly, they should test a wider range of skills than the mere recall of facts (paragraph 75).**

Coursework

- 27. We think that it remains important to assess practical skills at GCSE through coursework. But there is no point in continuing with coursework arrangements that have little educational value (paragraph 77).**
- 28. Coursework in science at GCSE needs a radical rethink. This is the responsibility of the awarding bodies but it is obvious that they are going to need significant encouragement from QCA. QCA should evaluate the coursework submitted in 2003, which will be the first to be submitted under the recently modified arrangements. If there is no significant change in the approach to investigative work, they should enter into immediate discussions with teachers and awarding bodies about how coursework could be changed to encourage more stimulating and engaging practical work in schools. In addition, we would like to see project work available to teachers as an option for GCSE coursework. This may mean reducing QCA's requirement that**

20% of GCSE assessment be based on investigative skills measured through coursework (paragraph 82).

Science for citizens and for scientists

- 29. We are convinced that science is essential for progression and for personal development and welcome DfES's decision to keep science as a compulsory element of the curriculum from ages 14-16 (paragraph 83).**
- 30. The challenge at 14 to 16 is to provide a secure foundation for those moving on to further scientific study post-16 and to give an understanding of science to those who do not; that is, to meet the needs of future scientists and of citizens (paragraph 84).**
- 31. Having taken the decision to keep science compulsory to age 16, DfES should include science in the requirements for any matriculation diploma (paragraph 85).**
- 32. What is important is not that citizens should be able to remember and recall solely a large body of scientific facts, but that they should understand how science works and how it is based on the analysis and interpretation of evidence. Crucially, citizens should be able to use their understanding of science, so that science can help rather than scare them (paragraph 86).**
- 33. On balance we believe that the advantages of increasing the priority given to the teaching of skills associated with scientific literacy at GCSE far outweigh the disadvantages (paragraph 88).**
- 34. It is important that students are able to follow GCSE courses that fully prepare them to continue with the academic study of science at A level (paragraph 89).**
- 35. We commend QCA for taking the initiative in piloting a new approach to GCSE science which aims to reconcile the need to prepare some students for further study and to give all students the skills of scientific literacy (paragraph 90).**

A new curriculum

- 36. We support the balanced science approach and believe that it should continue to apply for all students. However, within this, there needs to be flexibility and scope for choice by individual students to allow them to explore areas of interest (paragraph 93).**
- 37. All students should continue to spend 20% of their time studying science. At the same time, the National Curriculum at key stage 4 must be restructured to allow the development of a range of different science GCSE courses. This should enable students to choose courses that complement their abilities and interests in science. All GCSE courses should prepare students to feel confident with the science that they are likely to encounter in everyday life and provide a route to science post-16, either through traditional A levels or through vocational qualifications (paragraph 98).**
- 38. QCA should work together with stakeholders, including learned societies, teachers and students, to agree a National Curriculum that defines a minimum core of science that all students need to be taught at 14 to 16. This should**

include some of the key ideas in science across biology, chemistry and physics and a range of skills and understanding associated with scientific literacy. All qualifications in science offered at key stage 4 should then fulfil these revised National Curriculum requirements (paragraph 100).

- 39. A new science curriculum will need to define more explicitly the skills and knowledge associated with scientific literacy (paragraph 101).**

Assessment

- 40. Incorporating scientific literacy in the National Curriculum will not, on its own, be enough. If this aspect of the curriculum is to receive the attention that it deserves it must be given a higher priority in assessment (paragraph 102).**
- 41. Research and development needs to be undertaken to develop ways of assessing the skills associated with scientific literacy. This should be seen as an urgent priority and funded by Government (paragraph 103).**

Support for teachers

- 42. If science teachers are to be asked to teach a different curriculum at key stage 4, they will need time, resources and training. The Government must ensure that all three of these are available to teachers before implementing any major changes in science at key stage 4 (paragraph 104).**

Diversity

- 43. QCA should work together with the awarding bodies to develop a range of courses in science at key stage 4 that reflect the diverse interests and motivations of students (paragraph 105).**
- 44. The evidence from A level courses that focus on presenting science in contemporary and relevant contexts suggests that it is possible to attract girls to study physics and for them to enjoy the experience. This has lessons for the study of physics at 14 to 16. QCA should explore how the curriculum and assessment at key stage 4 could be adapted to reflect the positive features seen in the new physics A level courses (paragraph 106).**
- 45. We recommend that the Government consider how best to ensure the future of the Ishango after-school Science Clubs, if necessary by continued central government funding (paragraph 107).**
- 46. The African-Caribbean Network for Science and Technology recommends that the Government commission further research on race equality in science, maths and technology and explore ways of targeting resources on underachieving groups. It calls for science teaching materials to be developed to encourage multi-cultural and anti-racist teaching; and for teaching training and continuous professional development for science teachers to include these elements. We endorse these recommendations (paragraph 108).**

Specialist schools

- 47. We welcome the establishment of science and engineering specialist schools as a recognition that Technology Colleges, although numerous, are not representing the breadth of science and technology education. The Government should set a target for the number of science and engineering**

specialist schools within the overall target of 1,500 specialist schools by 2005 (paragraph 111).

48. We urge scientific bodies to consider how they can encourage and support schools to apply for science specialist status (paragraph 112).

A levels

49. In providing A level science courses it is difficult to strike a balance between attracting a broad range of students and providing the content needed for transition to science-based courses at university. The onus should be on universities to adapt to the changing nature of their intake. The Roberts Review recommends that the Government fund universities to use new “entry support courses” and e-learning programmes to bridge gaps between A levels and degree courses. We endorse this recommendation (paragraph 115).
50. On balance we are persuaded that the mathematical demands of school science at A level are appropriate. Where students need support with their maths, additional maths courses are available for schools to offer. Any increase in the maths content of A level science courses would risk alienating students further. Where universities require greater mathematical skills, they should take action to teach these themselves (paragraph 116).
51. The Government should ask QCA and the awarding bodies to explore how it would be possible to address the imbalance in grading across A level subjects (paragraph 117).

Vocational alternatives

52. FE colleges offer a range of science-based vocational courses linked to specific careers. These give students the opportunity to engage with science and achieve where they may previously have struggled (paragraph 118).
53. For those students who do not achieve grade C in GCSE science, there need to be intermediate qualifications available that will allow them to move on to AS and A level or VCE (paragraph 119).

Science for all

54. In evaluating the new AS and A level structure, the Government should look closely at whether the changes have successfully broadened the curriculum studied by post-16 students. If this is not the case, Government should consider the introduction of a compulsory post-16 curriculum, which would include science as one of its core subjects (paragraph 121).
55. Improving the experience of science at 14 to 16 in the ways that we suggest in this report should motivate students to consider studying science post-16. They should be provided with proper careers advice. Government should ensure that the careers service improves the quality of advice offered to school students about scientific careers and the breadth of career possibilities open to those with qualifications in science (paragraph 122).
56. We welcome the motivation behind the Government’s Science and Engineering Ambassadors initiative and look forward to seeing an evaluation of how effectively it is implemented and what impact it has (paragraph 123).

- 57. A benefit of requiring science to be taught using contemporary contexts is that it would encourage more science teachers to make use of local science based employers to support their teaching (paragraph 125).**

Laboratories

- 58. Good laboratory and prep room facilities are important because they enable high quality practical work to be carried out in a pleasant environment, motivating and inspiring staff and students alike (paragraph 127).**
- 59. It is appalling that the laboratories in one quarter of England's secondary schools are in such a poor state that the quality of teaching is being directly affected (paragraph 127).**
- 60. We welcome the £60 million committed to laboratory refurbishment by DfES; this should have made a significant impact. We are very surprised that DfES has not evaluated what impact this substantial sum of public money has had on those schools most in need (paragraph 128).**
- 61. We recommend that, over the next three years, the Government ringfence a minimum of £120 million to bring all school laboratories and prep rooms up to at least adequate standard. This money should be allocated direct to LEAs so that it can be targeted at those schools most in need (paragraph 130).**
- 62. DfES should ensure that schools are properly informed of the importance and costs of maintaining expenditure on science equipment (paragraph 131).**

Technicians

- 63. We expect to see action taken within the next year to address the appalling pay and conditions of science technicians and to create a career structure that will attract skilled and dedicated people to work as technicians (paragraph 135).**
- 64. It is essential that technicians have opportunities for professional development. This will mean not only making appropriate courses available but also ensuring that technicians have the time and funding to be able to participate (paragraph 136).**

Practical work

- 65. There is a widely held belief that practical work in schools is now constrained by health and safety regulations. This is simply not true (paragraph 137).**
- 66. The longer term aim should be to reduce secondary school practical science classes to no more than 20 students (paragraph 138).**

Motion for debate

67. We suggest the following motion for debate by the House:

“That this House takes note of the conclusions and recommendations in the Third Report of the Science and Technology Committee on Science Education from 14 to 19 (HC 508-1); notes the concerns reflected in that Report about the failure of GCSE science to prepare students effectively either for further study or for citizenship; accepts the need to revise the curriculum and reform assessment so that teachers have the flexibility to respond to students’ interests; acknowledges the work that has been done to develop new and innovative courses for both GCSE and AS and A level; recognises the vital role of practical work within science education and notes the poor quality of laboratories and the shortage of skilled technicians within many schools; and calls on Government to give urgent priority and sufficient funds to address these issues” (paragraph 140).

ANNEX 1: VISITS MADE IN THE COURSE OF THE INQUIRY

Committee visits

Tuesday 16 April 2002

Quintin Kynaston School, St John's Wood, London

Quintin Kynaston is an 11 to 19 mixed community school with around 1,000 students. Students are drawn from a very wide range of socio-economic and ethnic backgrounds. The school is in Westminster LEA and gained specialist Technology College status in July 2001.¹

The science department has 14 teaching staff, three of them part time, and three technicians. Most students take double science GCSE at key stage 4; some are entered for Intermediate GNVQ in science and others for entry level certificate. Post-16, Intermediate GNVQ is offered as a one year course and biology, chemistry and physics are offered to AS and A level.

Programme:

Tour of science department with Lez Weintrobe, previous Head of Science

Meetings with

Headteacher: Ms Jo Shuter

Technicians: David Langford, Agnes Szervansky and Justyna Wolanksa

Students: GCSE and AS and A Level

Teachers: Neil Bizzell, Nigel Gallimore, Jeff Ingham (Joint Curriculum Leader), Rozeena Khan (Joint Curriculum Leader) and Leonie Wilson

Tuesday 23 April 2002

Beeslack Community High School, Penicuik, Scotland

Beeslack is a mixed 12 to 18 school with some 980 students and is within the Midlothian Council area. The science department has 11 teaching staff and one technician. All science classes have a maximum of 20 students.

In Scotland, students will normally take Standard Grade courses from ages 14 to 16, which are broadly the equivalent of GCSE in England. At Beeslack, students take seven subjects at Standard Grade, which includes English, maths and at least one of at least one of biology, chemistry and physics. They study an eighth subject at Intermediate level, which is more challenging than Standard Grade.

Following recent reforms, there are now five levels of qualifications available in Scotland post-16 (Access, Intermediate 1, Intermediate 2, Higher and Advanced Higher), each of which is based on a one year course. The courses are designed so that students can progress from one level to another. Highers are broadly equivalent to AS levels in England and

¹ Further information about the school is available from their website: www.qkschool.org.uk

Advanced Highers to A levels. At Beeslack, students select five courses post-16. Biology is offered at Intermediate 1 and all three sciences at Higher and Advanced Higher.

Programme:

Presentation from Jack Jackson HMI.

Discussion with Douglas Buchanan (Moray House, University of Edinburgh), Frank Creamer (Scottish Executive), David Lawson (Science Adviser, Glasgow City Council), John Richardson (Scottish Schools Equipment Research Centre), and Dick Staite (Headteacher, Beeslack School), Walter Whitelaw (Education Officer, Midlothian Council)

Meeting with Standard Grade students: Catherine Ball, Lyndsey Holmes, Mark McBride, Allan Robertson, Katherine Smart and Sam Thomas

Meeting with Higher Level students: Kaashif Afzal, Roger Barnes, Graeme Devlin, Susan Gavin, Douglas Gibson, Kathryn Saunderson and Kate Thomson

Meetings with teachers and technician: Billy Dickson (biology), Sally Dunlop (chemistry), Michael Giblin (physics), Lesley Johnson (chemistry), Veronica Kinane (biology), Carolyn Williams (technician), Ian Wilson (chemistry)

Tour of science department.

Wednesday 24 April 2002

Westminster School, London

Westminster School is a selective independent school for boys aged 13 to 18 and girls aged 16 to 18. There are around 660 pupils, of whom about 200 are boarders (either full time or weekly) and about 90 are female.²

There are 15 science teachers in the department: six chemists, four biologists and five physicists who are supported by a team of seven technicians. Electronics and technology are also part of the science department. All students take at least two of biology, chemistry and physics to GCSE. All three sciences are offered at A level.

Programme

Tour of science department with Rod Beavon, Head of Science.

Meeting with GCSE students: Edward Eccles, Paul Giladi, Hamza Khan and Nick Wareham

Meeting with AS level students: Anthony Cardona, Charlotte Gloerfelt-Tarp, Joe Marwood, Ned Naylor, Tamsin Omond, William Stevenson and Karmen Watson.

Meeting with science and technology teaching staff and Ed Smith, Undermaster.

Meeting with technicians: Ransford Agyare-Kwabi, Clive Booker, David Davies, Anthony Tonini

² Further information about the school is available from their website: www.westminster.org.uk

Tuesday 7 May 2002

“Inward visit” by Hammersmith and West London College

Hammersmith and West London is a Further Education College that offers a wide range of courses to both 16 year olds moving on from school and to adults. Some 25,000 students enrol for courses each year with the college. AS and A levels are available in biology, chemistry and physics. Vocational courses that are offered include Intermediate GNVQ in science and VCE in science as well as courses that are linked to particular careers such as sports studies and beauty therapy.

The Committee held an informal meeting in the Houses of Parliament on the afternoon of 7 May with students and staff from the College.

Programme

Discussion with students

AS Level: Anita Quarcoo, Amanpal Singh

A2 level: Terry Harper, Ariola Gashi

AVCE: Pamela Aminou, Kirit Patel, Tawa Dugbazah, Joseph Ogundem, Bana Rashid, Dimple Vyas

GNVQ Intermediate (Science): Carlos Tapil, Emily Tondel

Hair and Beauty: Dorota Macalka, Sun Choi

Discussion with staff

Amrik Marhawa, division manager for science and electronics

Annette Prestidge, lecturer in biology and information learning technology co-ordinator

Rachel Ayton, lecturer, Beauty

Jayne Morgan, division manager for Human Development

Constituency visits by Members of the Committee

Friday 22 February 2002

Mr Mark Hoban

Visit to Henry Cort School, Fareham³

Mark Hoban MP invited science teacher representatives from secondary schools and colleges in his Fareham constituency to discuss issues around science education for 14 to 19 year olds.

Meeting attended by:

Ian Wilks, Fareham College (a further education college)

Brenda Robinson, Wykeham House School (an independent girls school)

Tracey Jones, Portchester Community School (an 11 to 16 mixed comprehensive school)

Chris Taylor, Henry Cort Community School (an 11 to 16 mixed comprehensive school)

³ A full note is printed at Ev 196

In addition, students at Portchester School gave written responses to the question “why do you do science?”.

Friday 1 March 2002

Dr Ian Gibson

Meeting with Norwich Science Teachers and Technicians

A public meeting was held by Ian Gibson MP at the Norwich Labour Centre to discuss science education from ages 14 to 19. The meeting was organised after consultation with Norfolk LEA and was advertised in the local press.

Those invited included:

Mr Stuart Baines, Alderman Peel High School
 Mr Roy Barton, School of Education, University of East Anglia
 Mr Richard Cranmer, Head of Science, Notre Dame High School
 Mr Stephen Cumberworth, Science Adviser, Norfolk Professional Development Centre
 Mr Frank March, Vice Principal, Thorpe St Andrew High School
 Mr Phil Millington, Head of Science, City of Norwich School
 Mr John Nicholson, School of Continuing Education, University of East Anglia
 Mr Hugh Strafford, Head of Science, Alderman Peel High School
 Mr Adrian Tebbit, Head of Science, The Park High School
 Mr Bernard Vaughan, Head of Science, Acle High School
 Mr Gordon Varley, Head of Science, Northgate High School
 Mrs Pauline Williamson, Science Technician, Costessey High School

Ian Gibson followed up the meeting by visiting the science departments of a number of local secondary schools, talking to staff and students.

Friday 19 April 2002

Dr Andrew Murrison

Visit to St Augustine’s Catholic College, Trowbridge, Wiltshire⁴

Andrew Murrison MP spent a day visiting St Augustine’s Catholic College in his Westbury constituency. St Augustine’s is an 11 to 18 mixed comprehensive with specialist technology college status. Dr Murrison asked the Headteacher to arrange for him to interview teachers, technicians and students during his visit.

Separate meetings were held with:

Mr Brendan Wall, Headteacher,
 Dr S Doherty, Head of Chemistry
 Mr D Greenwood, Head of Physics
 Mrs S Lewis, Head of Biology
 Senior Laboratory Technician
 A level students

⁴ A full note is printed at Ev 202

Friday 3 May 2002

Dr Brian Iddon Meeting with Bolton Science Teachers and Technicians⁵

Brian Iddon MP met with teachers and technicians from schools across Bolton.
Meeting attended by:

Margaret Blenkinsop, Director of Education and Arts, Bolton Metropolitan Borough Council
Mr Dave Chivers, Head of Science, Turton High School Media Arts College (an 11 to 18 mixed comprehensive)
Carole Deaville, Senior Laboratory Technician, Turton High School
Mr Dave Hayes, Head of Science, Mount St Joseph RC High School (an 11 to 16 mixed comprehensive)
Mr Robin Heap, Thornleigh Salesian College (an 11 to 18 mixed comprehensive)
Mrs Doreen Jolly, Rivington and Blackrod High School (an 11 to 18 mixed comprehensive)
Libby Mooney, key stage 3 Adviser, Bolton Metropolitan Borough Council
Mr Chris Profitts, Head of Science, Mount St Joseph RC High School

March-June 2002

Mr David Heath

David Heath MP visited three schools in his constituency.

Monday 18 February: Huish Episcopi School (11 to 16 mixed comprehensive)

He met and had discussions with science staff:

Paul McSparron, Head of Science
Science teachers: Anne-Marie Rogers, Clare Austin, E Hildred, Nicky Hill, John Merrick-Wren, Linda Paul, Mark Pembrey, Chris Storie

Friday 1 March: Frome College (13 to 18 mixed comprehensive)

David Winch, Head of Science
Science teachers: Russell Middleton, Chemistry; Matt Hoyle, Chemistry; Dave Titchener, Physics; Julia Padwick, Science Lab Technician

Friday 22 March: King's School Bruton (independent):

Paul Davies, Chemistry teacher and Head of Careers; Roger Low, Head of Science; Douglas Barns-Graham, Head of Chemistry; Simon Atkinson, Head of Biology; Dr Alan Atkinson, Head of Physics; Philip Barnes, Head of ICT

March-June 2002

Dr Bob Spink

Bob Spink MP visited SEEVIC College and various schools across his constituency to discuss, informally, issues surrounding science education for 14 to 19 year olds.

⁵ A full note is printed at Ev 200

ANNEX 2: INTERNATIONAL COMPARISONS

The Foreign and Commonwealth Office Science and Technology Unit has provided us with information about science education in 11 countries overseas: Canada (SED 91), Denmark (SED88), France (SED 104), Germany (SED 99), Iceland (SED 93), Italy (SED 105), Japan (SED 103), Netherlands (SED 86), Sweden (SED 89), Switzerland (SED 87), and USA (SED 90).

We asked posts the following questions:

1. What proportion of 14-19 year olds follow science courses including biology, chemistry and physics? Has this changed significantly over the last ten years?
2. What are the primary aims of the science curriculum for this age group (eg to provide a grounding for future scientists, to prepare students to engage with science as citizens etc)?
3. Do all students follow the same curriculum? Or are there, for example, academic and vocational options?
4. Is there perceived to be a problem regarding the relevance of the science curriculum? If so, is this regarded to be a particular problem for certain groups of pupils?
5. What is the place of practical work within the science curriculum? How is the practical work assessed?
6. How are pupils assessed on their knowledge and understanding? Is there perceived to be a problem with the assessment system?

Extracts from the responses are given below. The full submissions are available on request.

Canada

Education in Canada is a provincial responsibility. Curricula change from province to province, as do methods of assessment and school structure.

To graduate from school (aged 18, and seemingly most – around 86% in Ontario – students graduate from school), it seems most provinces require students to have at least two science credits, so most students take science until at least 16 (winning those credits in years 9 and 10).

In years 11 and 12, students have greater choice in the subjects they follow. Science is no longer a general course, but broken down into biology, chemistry, physics and earth sciences. Students in some provinces can graduate from school without taking a science subject in years 11 and 12. However, it seems that to qualify for a university course, even to read arts, a specific subject science course needs to be done in the senior years (many seem to opt for biology).

In some provinces (British Columbia, Ontario, for example), some schools appear to offer in years 11 and 12, a general science course. This is mostly directed at those not planning on an academic career and is often broad ranging, promoting science literacy. A general science course appears also to be available in Alberta in year 12. This was apparently designed to be more academic and suitable for university entrance-level students. However, take up is apparently low due partly to stigma and the fact it is also perceived to be very difficult.

As for numbers taking these subjects, according to Alan Taylor of Applied Research and Evaluation Services at the University of British Columbia, best estimates are about 14% of age cohort enrolled in grade 12 physics (he suggests this is about 20% of the grade cohort). He suggests a similar number for chemistry, but considerably greater numbers for biology.

According to the Education Quarterly Review, 2001, from Statistics Canada (vol 8, no 1), in 1995, 42% of students were taking both maths and at least one science in their last year of school. However, just over a fifth (20.8%) of all upper secondary students were enrolled in neither maths nor science. 18.6% were taking maths but not science, 18.4% science not maths.

In 1995, education ministers from across Canada (except Quebec) adopted the Pan Canadian Protocol for Collaboration in School Curriculum. The Pan-Canadian Science Project was the first project under the protocol, and aimed at producing a framework of general and specific science learning outcomes for kindergarten to grade 12. The framework is to assist curriculum development in each jurisdiction.¹

The second page (titled, A vision for scientific literacy in Canada) states:

“The framework is guided by the vision that all Canadian students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy. Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them”.

Hence science literacy seems to play a crucial role in Canada’s science education vision.

Julia Hinde
First Secretary (Science and Technology)
British High Commission, Ottawa

Denmark

There is a belief in Denmark that it is lagging behind other countries on the science front, and certainly the latest PISA survey has shown that Danish students (age 15) are far behind in natural science subjects (only 7 countries do worse than Denmark). Other surveys for students at age 19 however have shown that students are above average in science at this age. But there is a general feeling that more needs to be done to improve the Danish students’ science record and generally engage more students in the subjects, although no policy initiatives that we are aware of are planned at present.

Statistics show that during the last ten years interest in science subjects have dropped. This is true both if one looks at the age group 15/16-19, but also if one looks at the number of students enrolling at university courses such as natural science. The trend is a steady decrease.

The Danish Employers’ Federation has recently completed some research relating to education of the 15-19 year age group. Some of this looks at science education in broad terms.

The Danish Employers’ Federation’s research also included an analysis of the subjects taught at the Danish ‘Gymnasium’. This showed that the level at which students choose to study the subjects are dropping whether it be in the maths or the language line. A student can choose either level A, B or C. Students must take some subjects at level A, but it is a problem if the subjects chosen at level A are not what might be called core subjects ie maths, physics etc. According to the Danish Employers’ Federation, the choices at Gymnasium have become too

¹ <http://www.cmec.ca/science/framework/index.htm>

wide, the maths or language lines have consequently become diluted, students are not strong enough in the core subjects, and subsequently find it difficult when starting higher education.

The survey done by the Danish Employers' Federation suggests that there is a discrepancy between what is taught and what is required at the exam. Across the board the marks given at exams are lower than those given by the teachers at end of year assessment.

The Federation would like to see more linking with industry also in the hope that this could make the teaching more interesting and thus attract more students. A summary of a pilot project which aims to make science more interesting is available on the internet.²

There are no surveys or analysis which looks at science education at lower secondary schools, but the PISA study suggests science is not given a high enough priority. Physics and chemistry is taught from 7th grade (age 13) and teaching is at many schools to a large degree practical exercises. The students also have to do a practical test at the exam (there is no written examination). In maths, students have both a written and an oral test where the oral test includes a practical test. There is no examination in biology or geography.

British Embassy, Copenhagen

France

Key Points

- Science is holding up well as an option for secondary school pupils; “Bac S” (the scientific Baccalauréat) remains the most prestigious option for sixth formers and attracts many academically-gifted pupils destined for non-scientific careers/higher education.
- Even for those taking “Bac L” (literature), science and maths remain compulsory subjects and will continue to be taught until at least the lower sixth.
- Despite a slight weakening in its position, mathematics remains the cock of the roost. Performance in maths is regarded as a key yardstick of academic excellence.
- Main problem is recruitment for science-based courses at university. Physics and chemistry have seen particularly sharp drop in numbers.
- Substantial growth in vocational courses over past twenty years. Around half of all those obtaining Baccalauréat now come from vocational streams (“Bac technologique” or “Bac professionnel”).
- Efforts have been made to liven up school curriculum and make science teaching more “hands-on”; but criticism of theoretical bias persists.

At collège [11-15], all pupils study science. In terms of the number of hours devoted to science teaching at collège, France is slightly above the average of OECD countries for the 12-14 year old age group. The principal aim of the science curriculum at this level is to equip pupils with an adequate scientific grounding (“culture scientifique”) to allow them to make sense of the world around them; a subsidiary objective concerns familiarisation with the experimental method.

Science is divided into two main subject blocks: biology/environmental science and physics/chemistry. The former is taught from the sixième, whilst the latter is introduced in

² See <http://pub.uvm.dk/2000/nklasser/10.htm>

cinquième. 14-15 year olds (troisième) in a biology class, for example, will learn about genetics and the basics of cell metabolism. In physics, they will learn about electricity.

In the lycée [15-18], all pupils studying academic courses leading to the general baccalauréat (S, L or ES) will study a core science curriculum in seconde. This comprises 3.5 hours per week of physics/chemistry and 2 hours per week of biology/environmental sciences. In addition, pupils choose two optional subjects from a list of seventeen which will help to determine their specialisation for the Baccalauréat in première and terminale. A pupil expecting to do a Baccalauréat S is advised to choose one science option (eg introduction to engineering) plus a second foreign language. In their final two years, pupils following the Baccalauréat S can expect to spend around 16 hours per week on maths and sciences combined, from a total timetable of 26 hours. Those opting for additional maths can expect to divide their time roughly equally between maths and science; but even those specialising in one of the science subjects will find maths taking up around 6 hours per week.

The additional maths option remains the most prestigious choice. Figures for the Lille Académie in 2001 show that around 30% of pupils in this option went on to obtain a place in the “classes préparatoires” – two-year courses preparing for the highly competitive entrance exams for the Grandes Ecoles. This figure is significantly lower for the physics/chemistry (16%) and life sciences/environmental sciences (6%) options.

Teaching methods are less open to objective analysis than curriculum content. There appears, however, to be a feeling that science teaching has tended to err on the side of the theoretical at the expense of the practical, setting too high a premium on rote-learning and too little store by practical/experimental work. In short, a fact-based, teacher-centred style of learning has taken precedence over discovery-based, pupil-centred style of learning. Some weight for this view would appear to be lent by the findings of international surveys of pupils' performance, where French children habitually produce their best scores in solving theoretical problems rather than applied ones.

*Andrew Holt
British Embassy, Paris*

Germany

The Federal Republic of German comprises sixteen Laender (states), which have exclusive jurisdiction in the educational sphere.

Compulsory schooling commences at the age of six and finishes at 18. Nine (or ten) of these years have to be spent in full-time schooling: the following years either in full-time schooling or part-time vocational schools, eg in connection with an apprenticeship.

Secondary education is divided into:

(A) Lower secondary level education (10 to 16) is differentiated according to young people's ability, talent and inclination:

- the Hauptschule (grades 5- 9/10) which provides a sound basis for vocational training
- the Realschule (grades 5 or 7-10) which prepares students for careers with higher demands
- the Gymnasium (grades 5-10) which prepares its students for higher education;

(B) Upper secondary level education (16 to 19 year old pupils).

14 to 16 year pupils: the subjects are taught separately as biology, chemistry and physics. The three science subjects are part of the core curriculum, and all students must study them.

The extent to which the three subjects are taught varies according to the type of school as well as the Laender. Biology and physics are not normally taught in every grade, and chemistry teaching is usually begun later than the other two sciences.

16 to 19 year old pupils: Two of the three sciences are compulsory in the first year of upper secondary. At least one of the chosen science subjects must be contained in year two and three.³

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Japan

All pupils in Japan take science education courses at lower secondary schools (ages 12 – 15).

The Ministry of Education, Sports, Culture, Science and Technology (MEXT) stipulates the educational objectives, goals, curricula, school week and subject types taught at different school levels based on the School Education Law. Contents of all subjects are also stipulated in Courses of Study. Courses of Study were comprehensively revised in 1998 and will be effective from April 2002 for lower secondary schools and from April 2003 for upper secondary schools, respectively.

Primary aims are:

To develop scientific investigation ability and deepen their understanding of matters and phenomena in nature by arousing interest in nature and through observations and experiments, thereby developing scientific views and thinking.

To master methods for discovering and explaining natural phenomena through the process of investigating problems among matters and phenomena concerning substances and energy.

To acquire skills in observation and experiment through observations and experiments of chemical matters and phenomena, and to understand familiar substances and their changes, and chemical changes, atoms, molecules, ions, etc, thereby developing a scientific way of viewing and thinking about these phenomena.

To acquire skills in observation and experiment through observation and experiments of physical matters and phenomena, and understand familiar physical phenomena, electric current, motions, energy, etc, thereby developing scientific ways of viewing and thinking about these phenomena

To arouse their interest in matters and phenomena concerning subsistence and energy, and positively undertake activities of investigation, thereby developing an attitude to consider these phenomena in relation with daily life.

Through these measures MEXT is developing “easy-to-understand classes, where students are able to experience the joy of learning and a sense of achievement, and cultivating “a zest of living” (Ikiru chikara in Japanese) in children”.

All pupils at lower secondary school follow the same curriculum. After a standardised first year, pupils at upper secondary schools can choose their study courses. Upper secondary school

³ Details are available in English in Riquarts K and Wadewitz C, *Framework for Science Education in Germany*, IPN 2001.

courses are classified into three categories: general, specialized and integrated courses. The specialized courses are further classified into agriculture, engineering (mechanical, electric, electronics and information technology) commerce, fishery, home economics, nursing, science-mathematics, physical education, music, art and English language. Curricula of upper secondary schools are based on the Course of Study, issued by MEXT.

In recent years courses have become more relevant with such issues as environmental pollution and global warming being emphasised more. In addition to the course material, there are science clubs which can be well utilised.

The Science Education & Research Association has pointed out that the importance of science in the curriculum has been decreasing as reflected in the number of credits for science education at upper secondary schools (ages between 15-18). The reduction in time available for science is also leading to a reduction in the time available for experiments and other practical work for pupils between 12 and 18.

Assessment of science, including practical work, is conducted by individual schoolteachers. Pupils' knowledge and skills are assessed on their interest, desire for, and attitude to science matters; their judgement, and observation ability; their ability to conduct experiments, presentation knowledge and understanding.

The Japanese Ministry of Education, Culture, Sports Science and Technology (MEXT) has recently announced proposals to launch a "Science Literacy Enhancement Initiative" including a scheme to create "Super Science High Schools"

There are eight initiatives under the Science Literacy Enhancement initiative with a total budget of around ¥5.6 billion (£31 million) this financial year.

MEXT are designating 26 schools as "Super Science High Schools" each of which will receive an additional subsidy this year of ¥25 million (about £136,000) out of a total allocation of ¥727 million (around £4 million) to run the scheme this financial year. The scheme will run for three years. It is not yet clear whether there will be additional subsidies in future years as this will depend on the budget available to MEXT.

The aim of the scheme is:

- to create elite pupils
- to develop a special curriculum particularly on science and mathematics
- to prepare lectures to be given by university professors
- to provide opportunities to have lectures at universities and research institutions
- to conduct research into education methods to improve logical thinking, creativity and originality, and assist the activities of science clubs
- to provide opportunities to meet top class scientists and engineers to learn about advanced technologies
- to provide the opportunity for exchanging students between super science schools.

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Netherlands

The Dutch education system comprises primary, secondary and higher education. Primary education is compulsory from the age of five and lasts for eight years. Pupils' performance in the upper years of this phase determines the type of secondary school they should attend.

Secondary education, which starts at the age of 12 and is compulsory until the age of 16, is divided into two consecutive vocational programmes, VMBO [junior secondary pre-vocational education] and MBO [secondary vocational education] and two parallel programmes, HAVO [senior general secondary education] and VWO [integrated pre-university education]. The programmes vary both in length – from four to six years – and in the difficulty of their respective curricula, ie from vocational training (MBO) to university preparatory education (VWO). In general, students in Higher Professional Education will have graduated from a HAVO, VWO or MBO programme.

The 15 – 19 year age bracket starts somewhere during the last two years of HAVO and VWO, which are described in educational terms as the “Tweede Fase”, (Second Phase). Pupils can make a choice as to how they wish to continue their study according to four profiles: Nature and Technology; Nature and Health; Culture and Society and Economy and Society. The latest available statistics from the Ministry of Education show that 15.8% selected Nature and Technology; 16.7% Nature and Health; 5.4% a combination of both; 17.9% Culture and Society; 36.9% Economy and Society; 4.9% a combination of both and 2.4% were still undecided at the time of measurement.

In spite of all the promotional campaigns, fewer and fewer young people are choosing technical careers. The figures for new entrants to all technical sectors and all education levels have been falling for years, from metalworking to chemistry, from pre-vocational secondary education to university. It is felt by many that young people see science and technology as too narrow an option; they associate it with dull research and manufacturing jobs in laboratories or factories, with no opportunity for promotion to management posts or progression to running their own business. Technology, as they believe, offers far fewer opportunities on the jobs market than, for example, economics or a general education.

The Dutch Government recognized that the shortage of people trained in the sciences and technology began to become a problem around 1998. It instituted Axis, an organisation which has a project portfolio to stimulate young people into science and technology studies. Co-funding of Axis activities is currently more than 50% – now just under euros 18 million – providing good evidence of Axis’ ability to mobilise parties in the market. More than euros 4.6 million of this co-funding comes from the business community. Two studies commissioned by Axis (Technomonitor, 2000 and Bèta/Techniek uit Balans, 2000 (Science & Technology out of Balance) indicate that the problem needs to be tackled at a more fundamental level than in the past.

The creation of challenging study design modules is the central plank of the national project Technology 15-plus, an Axis activity. It creates practical assignments and projects in the second cycle of secondary education. Support is being provided for the design activities in four regions (Eindhoven, Rotterdam, Groningen, Enschede) by regional networks in collaboration with providers of technical education and the regional business community. The aim of the project is to encourage senior general secondary (HAVO) and integrated pre-university (VWO) students to choose science and technology by embedding ‘custom education’ in the second cycle of their secondary education.

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Sweden

All subjects in the Compulsory school [7-16] are mandatory. A total of 12% of the Compulsory school curriculum is devoted to Biology, Chemistry, Physics and Technology. All science subjects aim to describe and explain nature and living organisms from a scientific

perspective. Developing pupils' curiosity about, and fascination for, nature in general terms as well as their interest in everyday phenomena is also an aim common to the science subjects at this level.⁴

Upper Secondary Schools [16-19]: In the academic year 2000/2001 50.9% of students on National Programmes followed vocational programmes. Of those following academic studies, 40.8% followed the Natural Science programme and 59.2% chose Social Science.

All the Upper Secondary School national programmes, including the vocational ones, cover a broad variety of subjects. A basic course of science, the Science studies A course, is included on all national programmes. Students studying the academically oriented Social Science Programme also follow the Science studies B course. Both these courses are interdisciplinary subjects. On the academically oriented Natural Science Programme Biology, Chemistry and Physics are taught separately in addition to Science studies A.

Science studies A aims to provide the knowledge of science necessary for people to engage with it as citizens. This includes knowledge of the growth of scientific world-views and the history of the universe and the earth as well as the capability of distinguishing facts from value viewpoints in a debate. Understanding of the connection between lifestyle and sustainable ecological development is also stressed. Pupils should be able to carry out simple experiments and analyse and interpret the results of these. Science studies A accounts for 2% of the total Upper Secondary School curriculum in all programmes.

Science studies B is the course common to the Social Science Programme. Goals to attain include having knowledge of the theories of the natural sciences concerning the origins, conditions, development and diversity of life. Pupils should be able to describe the structure and function of the living organism, from the molecular level to the level of the organism. Knowledge of modern genetics and genetic engineering, as well as the capability to discuss the application of these from an ethical perspective is another goal. Time is also devoted to teaching the importance of lifestyle to promote health. Science B accounts for 4% of the total Social Science Programme curriculum.

The Natural Science Programme is intended to lead to Higher Education studies in Science or Technology. Students can choose from a variety of 'orientations'. All orientations include Biology, Chemistry and Physics A, which each account for 4% of the total curriculum of the programme. Depending on which specific orientation students choose they may also study some or all of Biology, Chemistry and Physics B, as well as different courses particular to each specific programme (Environmental studies, Computer Studies etc) In total science subjects related to the specific programme account for 12% of the programme curriculum, making a total science content of 26% (including Science studies A).

The Natural Science Programme aims to provide scientifically based knowledge of the conditions of life and of nature and also aims to develop the ability to use mathematics in the natural sciences and in other areas. Courses in the programme involve a combination of experiments and the studying of different theories within the field. Environmental and resource issues are an important part of the programme. Students are also expected to be able to take an active part in debates related to the particular subjects of their orientation by the time they have completed the programme.

Compulsory school includes national tests in Mathematics at age 12 and 16 but not of the other science oriented subjects. In Upper secondary school the Natural Science Programme includes national tests in Mathematics and Physics. Contacts at the National Agency for Education explain the lack of national testing in Sweden as a result of the emphasis placed on

⁴ See <http://www.skolverket.se/pdf/english/compsyll.pdf>

acquiring knowledge that can be used in everyday situations or in future working life, i.e. on applying knowledge achieved, rather than on memorising exact facts. This priority makes it more difficult to carry out national tests.

Contacts at the Swedish Ministry for Education say there is a clear political ambition in Sweden to increase interest in science and technology among pupils. A number of actions have been taken to meet this goal, including:

- New curriculum – Ever since new curricula and syllabuses were introduced in Sweden by the middle of the 1990s, the amount of time devoted to scientifically oriented subjects and technology has significantly increased in Compulsory school. In Upper secondary school Mathematics A and Science A are, as a consequence of the new curricula, taken by all pupils.
- Bridging courses – One-year science courses designed to allow students with insufficient science background to qualify for science studies at university. This is thought of as a very successful way of recruiting more students for studying science and technology at university. It is also deemed to be a good way of recruiting more students to teacher training within science and technology.
- The NOT (Science and Technology) Project – In 1993 the Swedish government tasked the National Board of Education and the National Agency for Higher Education with running a project aimed at increasing interest in science and technology. The mandate was renewed in 1998 with instructions for special emphasis to be put on change of attitudes towards science and technology among pupils and methods used for teaching these subjects at school and university.⁵
- Resource Centres – The Swedish government has established special Resource Centres within the fields of chemistry, physics, technology, mathematics and most recently within biology and biotechnology at different universities around the country. These centres are responsible for supporting development of the subjects mentioned within schools and for supporting teachers and teacher trainers working within this field.
- Science centres – Economic support is given to a number of science centres across Sweden. These centres contribute to science education in different ways, for instance by arranging school visits and by designing experiments for classroom teaching.
- Raising of teachers' competence – Financial support of 75 million SEK (around £5 million) has been given to raising Compulsory schools' teachers' competence within the fields of science, technology and environmental issues. This was due to an assessment that the majority of teachers teaching at Compulsory school are considered to lack both sufficient theoretical and pedagogical knowledge of these subjects.

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USA

Science teaching is the focus of continual but low-level attention amongst US policy-makers, both in Washington and State capitols, driven by concern in universities and industry who worry that not enough high school students are opting to do science. However, there is no

⁵ <http://www.hsv.se/NOT/SciTech.htm>

fully national agenda or national philosophy on the teaching of science in schools and it is important to appreciate that individual States have much discretion over the curriculum, teaching, student assessment and funding.

In Washington, the focus tends to be on standard-setting and assessment. There is also a general concern about the supply of scientists and engineers, thrown into sharper relief following the events of September 11th and the October anthrax crisis, which highlighted the large numbers of foreign science and engineering students. As a result more attention is being paid to improve the flow of scientists and engineers from US schools. Last summer, the National Science Foundation was asked by Congress to manage an initiative to enhance the teaching of maths and science in schools from Kindergarten through to 12th Grade (K-12 Math-Science Partnerships). The program invites school districts, universities and other organisations to bid for funds to create a partnership to support local science teaching and has generated much interest. The first round of applications is to be sifted over the summer.

The teaching of science in individual states is overseen by State School Boards, and often influenced by local political considerations. In many States, the attention given to science teaching is driven by the nature of the local economy. In states where hi-tech clusters, entrepreneurship and basic R&D are seen as major drivers of growth – such as California, Massachusetts and Maryland – there is a strong focus on teaching science in schools, often supplemented by the activities of private or non-profit organisations. The interfaces between school and higher education, and between higher education and industry are of much interest. In other states, the debate on science teaching can occasionally be hijacked by strong views on the teaching of evolution, with creationism and intelligent design competing for attention alongside Darwinian theory.

There are two general features of science teaching in the US which differ from the UK and are worth highlighting. Firstly, from an early age there is much emphasis on individual science projects, with a tradition of presenting the results at school science fairs – from local school districts up through to County, State and National levels. From my own experience (visiting local elementary schools and the AAAS young scientist poster fair) the projects can be impressive. They range from home-built apparatus set up in the garage at home through to high school students working out of hours on projects with research groups at local universities or institutes.

Secondly, the long school summer holidays provide ample opportunity for summer camps – another US tradition. Frequently these camps offer students the opportunity to focus on a particular speciality (eg sports) or to build on specific elements of the school curriculum. The Center for Talented Youth at Johns Hopkins University, for example, offers a program of maths, science and writing camps for gifted children across the US; others offer to help improve the performance of students who are slipping behind.

Horizon Research conducted a study on practical science work which further illuminates the role of science projects. 71% of science classes for secondary school age students involve practical work at least once a week, with an average of 22% of class time spent on practical work. In the UK practical work tends to be conducted within one science lesson, but in the US, in addition to short classroom experiments, American high school students participate in long-term science projects, completed over a period of several weeks. Unlike practical work in the UK, these long projects are conducted entirely out of school time. Students decide what the project will be based on, which fosters creative thinking and an interest in science. The project apparatus is usually displayed alongside a written report in a science fair, attended by parents, and graded by a panel of science teachers. Students are required to briefly discuss their work with an assessor, and prizes are awarded. Class practical work assessment is similar to that in the UK, with the emphasis on a written report using the scientific method.

But what does the system achieve? There is some evidence that the assessment system in the US, particularly for science subjects, is failing to highlight students' underachievement. Although US students are among the most proficient in science internationally aged 10, by 18 they have dropped to become one of the worst performing countries. The longer American school students study science, it seems, the worse their grasp of it. This suggests that either the methods of instruction or the assessment system, or both, are not serving US students effectively. As testing is often infrequent in American high schools, recent standards-based reforms, supported by President Bush, encourage more regular testing. Hence debates currently focus on the fundamental issue of providing assessment, rather than improving the types of assessment used.

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ANNEX 3: STATISTICAL ANALYSIS OF THE TAKE-UP OF SCIENCE POST-16

1. We have obtained two different sets of data that show entries to science and maths A levels over time. The first, provided by the awarding body AQA, is based on candidates for all awarding bodies across England, Wales and Northern Ireland in a particular year and goes back to 1985.⁶ The second, provided by DfES, isolates those aged 17 in England at the beginning of an academic year and shows any A level results that they may have accumulated over that and the previous two years. This data has been provided back to 1992, when the method for collecting such information was changed. Figure A1 below shows the entries to science and maths A levels from each set of data.

Figure A1a: Graph showing the number of entries to science and maths A levels by candidates of all ages in England, Northern Ireland and Wales.

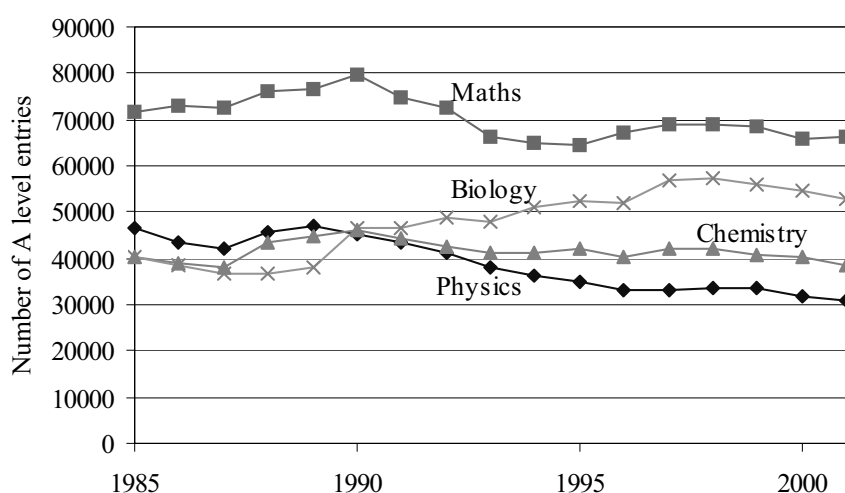
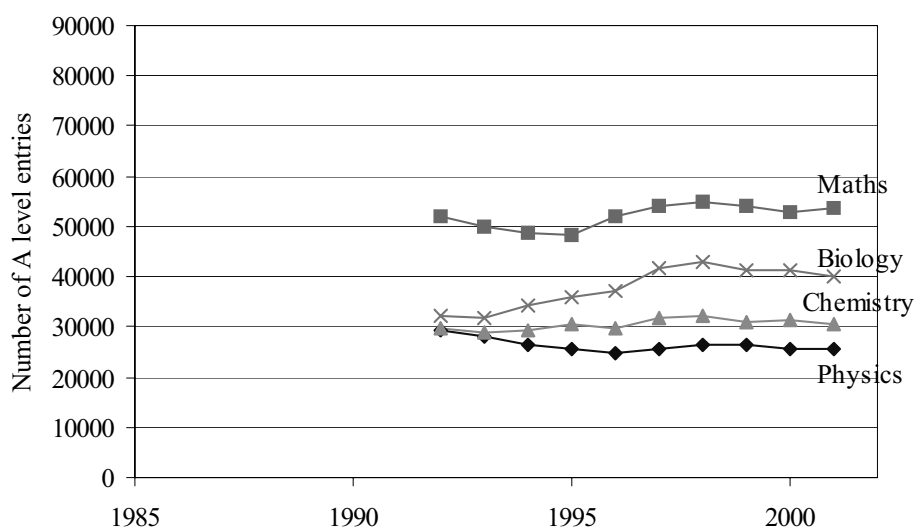


Figure A1b: Graph showing the number of entries to science and maths A levels by 17 year olds in England.

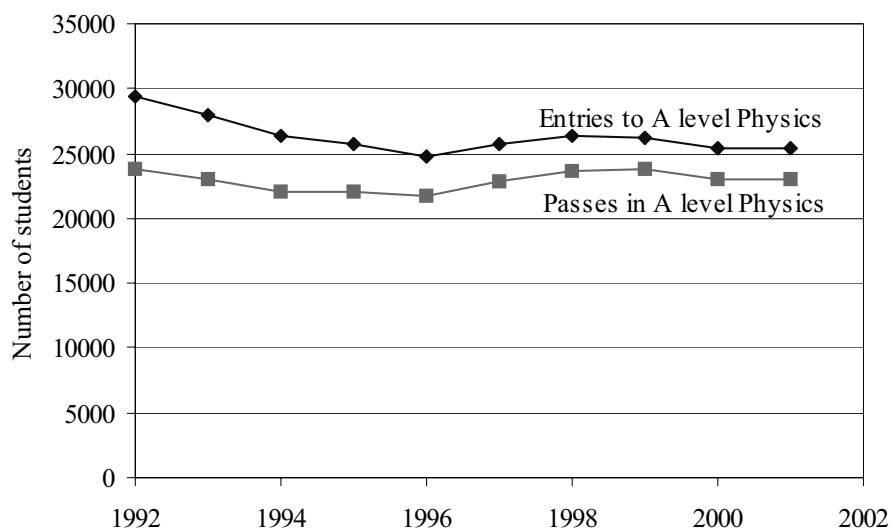


⁶ This data has been collated by the Institute of Physics and is available from www.iop.org/Policy/Statistics

2. The two sets of data show similar, but not identical, patterns. After increasing through the early and mid 1990s, entries to biology A level are now starting to fall. In chemistry, the numbers have remained, on average, static. Entries to physics, after decreasing significantly in the early 1990s, have now stabilised. In figures A2-A4, we have chosen to use the data provided by DfES for entries from 17 year olds. This is because we are primarily interested in those students that are moving directly from GCSE into A level and the influence that their experiences at GCSE have on their subject choices and level of attainment. In addition, this report focuses on the situation in England only.

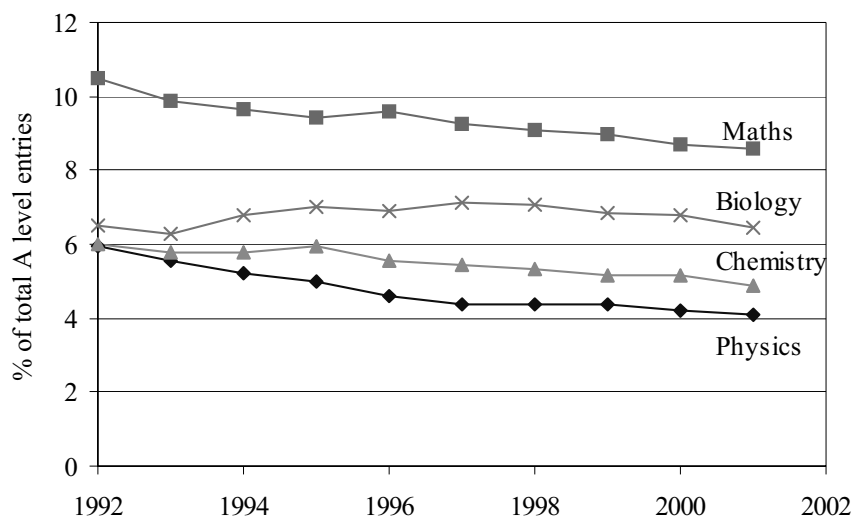
3. Figure A2 compares the number of students entering A level physics with the number that successfully pass the exam at grades A-E. While the overall trend is similar in both cases, it is not identical. Between 1992 and 1996, the number of entries to A level physics fell by over 15% while the number of students passing the exam fell by less than 9%. This reflects the rising pass rate: in 1992 the pass rate was 80.6% and in 1996 it was 87.4%. Since then the pass rate has risen more slowly and in 2001 was at 90.3%. This is why the numbers passing and entering physics A level have mirrored each other more closely over the last 5 years. In all other figures we have chosen to use the data showing the number of entries to a subject. This is because, in this inquiry, we are primarily interested in the choices that students are making at age 16. For those interested in, for example, the take-up of physics at university, it may be more appropriate to look at the data showing attainment at A level.

Figure A2: Graph comparing the number of entries to A level physics with the number of passes at grades A-E over time.



4. Between 1992 and 2001 the overall number of A level entries increased by 26%. Figure A3 shows the proportion of these entries that came from science and maths. Only biology has maintained its “market share”. Chemistry, physics and maths are becoming steadily less popular choices with students.

Figure A3: Graph showing entries to science and maths A levels as a percentage of all A levels entries over time.



5. Figure A4 shows the number of entries to biology, chemistry and physics A levels by gender. Since 1992, the proportion of entries to physics from girls has remained fairly static at just over 20%. Similarly, the proportion of entries to biology from boys has remained fairly static reaching a high of 40% in 1996 and 1997 and falling back to 38% by 2001. Chemistry is where the change has occurred. In 1992, boys made up 59% of A level chemistry entries. By 2001 the numbers of entries from boys and girls were split almost evenly; 50.4% of entries were from boys.

Figure A4a: Graph showing the number of entries to biology A level by gender.

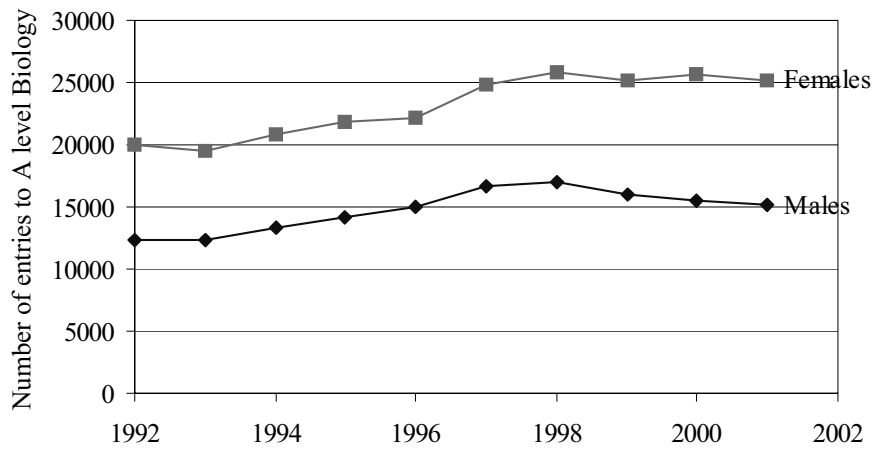


Figure A4b: Graph showing the number of entries to chemistry A level by gender.

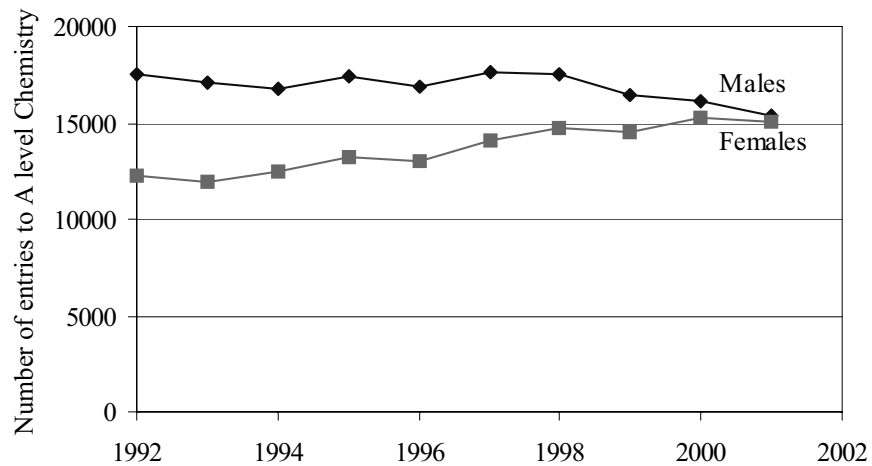
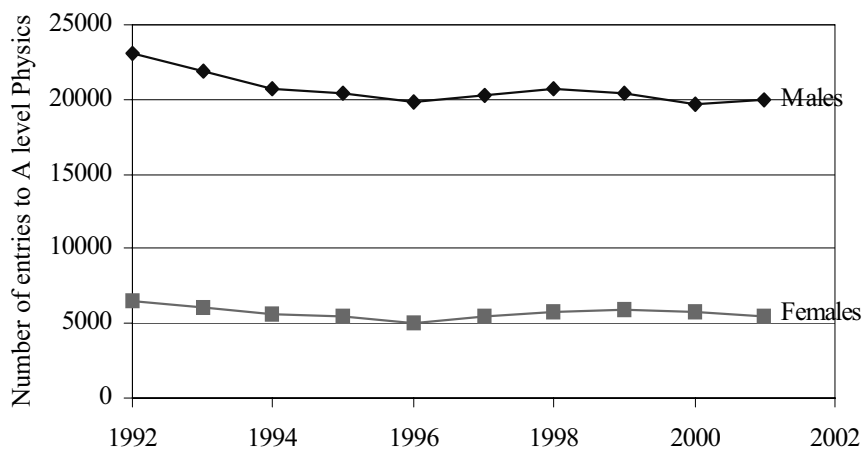
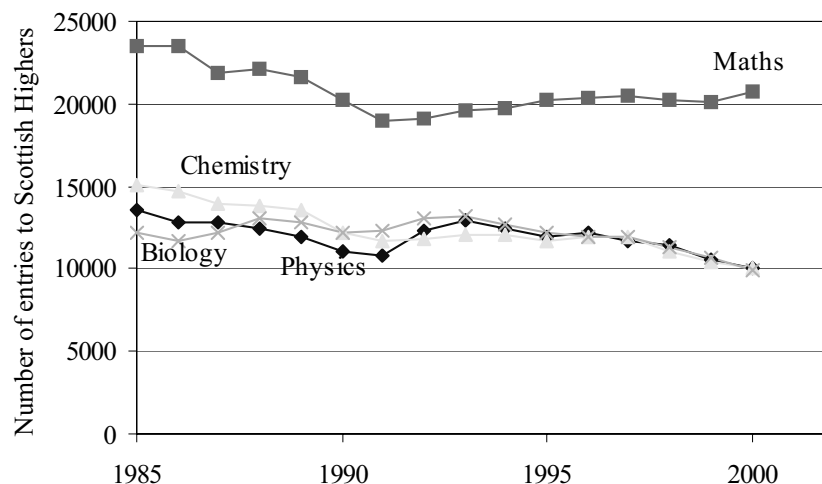


Figure A4c: Graph showing the number of entries to physics A level by gender.



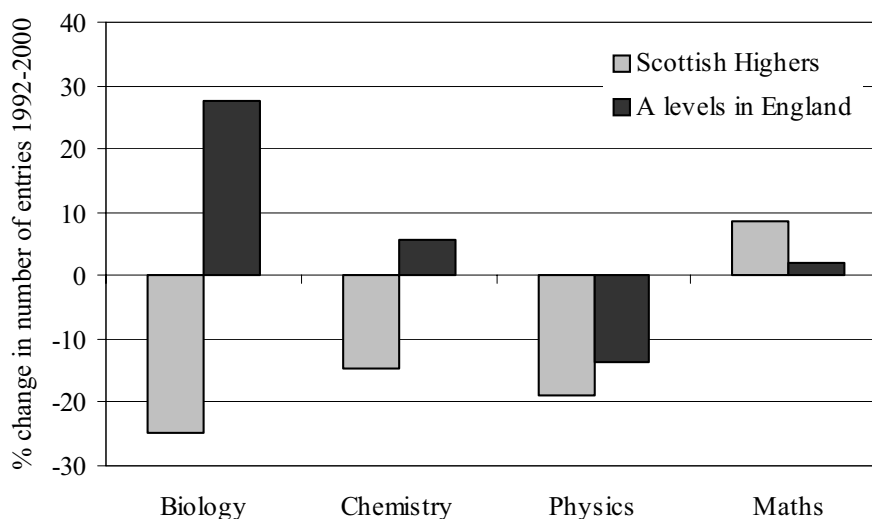
6. In Scotland, students typically enter 4 or 5 subjects at Higher level at age 17. Figure A5 shows the number of entries to Scottish Highers in the sciences and maths. It is based on data provided by the Scottish Qualification Authority (SQA).⁷ These subjects are attracting progressively fewer entries, as in England. Unlike England, the three sciences are equally represented in Scotland.

Figure A5: Graph showing the total number of entries to science and maths Scottish Highers.



7. The graph in figure A6 compares the change in the number of entries to A level subjects in England by 17 year olds, to change in the number of entries to Scottish Highers. This has been calculated from 1992-2000 because this is the longest time period over which we have comparable data. There was a rise in entries to biology and chemistry in England over this time period, at the same time as entries were falling in Scotland. The fall in entries to physics in Scotland is greater than that seen in England. By contrast, a greater increase in the take-up of maths has been seen in Scotland.

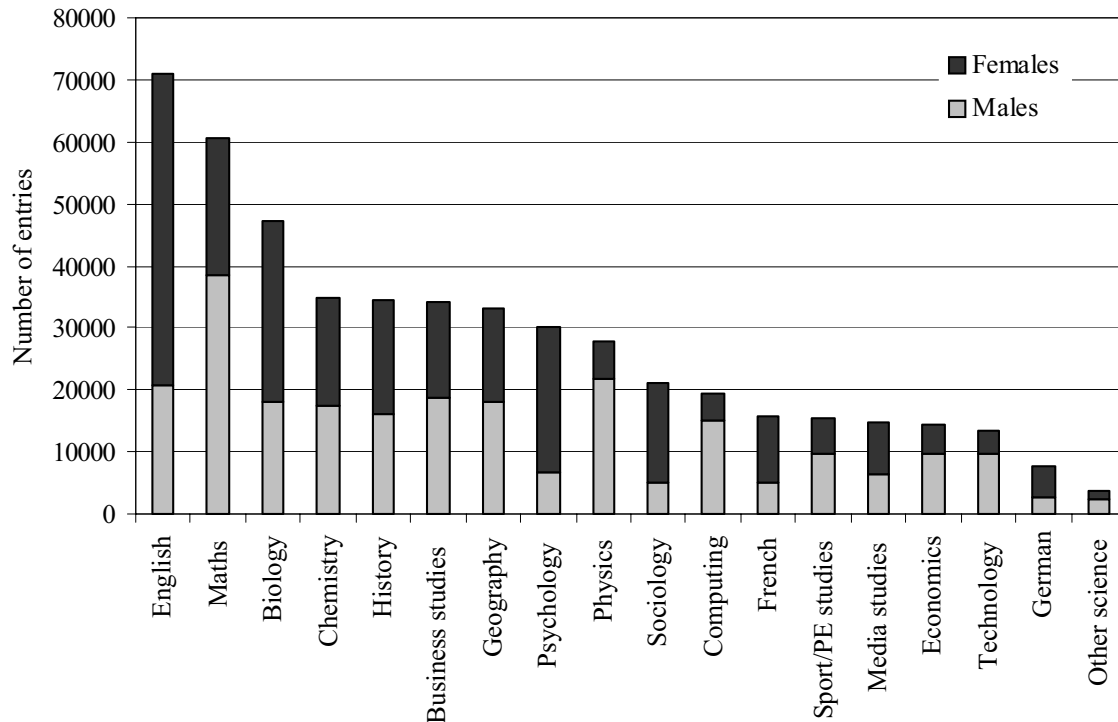
Figure A6: The percentage change in the number of entries to Scottish Highers and A levels in England between 1992 and 2000.



⁷ This data has been collated by the Institute of Physics and is available from www.iop.org/Policy/Statistics

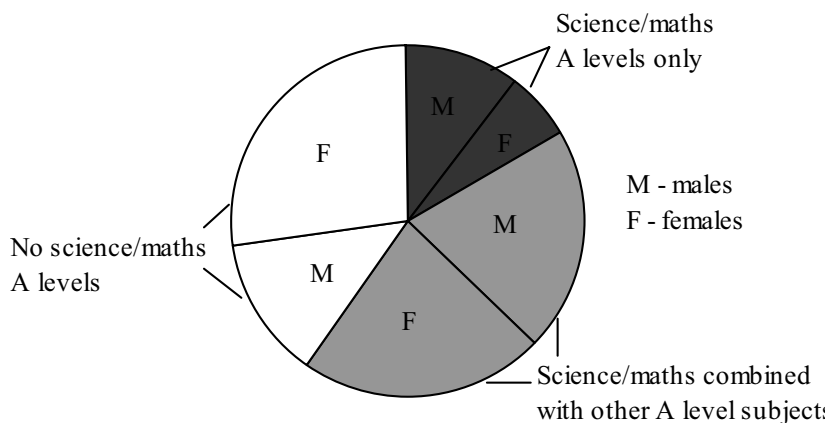
8. Figure A7 shows the number of candidates entering selected A level subjects in 2001. The data is for candidates of all ages in England as collated by the Joint Council for General Qualifications.⁸ English is the most popular A level, followed by maths, biology and chemistry. Physics lies not far behind. The sciences remain popular choices at A level.

Figure A7: Graph showing the number of entries to selected A level subjects in 2001.



9. Figure A8 is based on the numbers of 17 year olds in schools and colleges passing three or more A/AS levels in 2000.⁹ It shows those passing science and maths subjects only, science or maths combined with other subjects and those not studying science or maths at all. Overall, 60% of students passed at least one science A level. This comprised 70% of males and 50% of females. Twice as many girls as boys did not pass any science subjects at A/AS level.

Figure A8: Pie Chart showing the AS/A level subject combinations passed by 17 year olds in 2000.

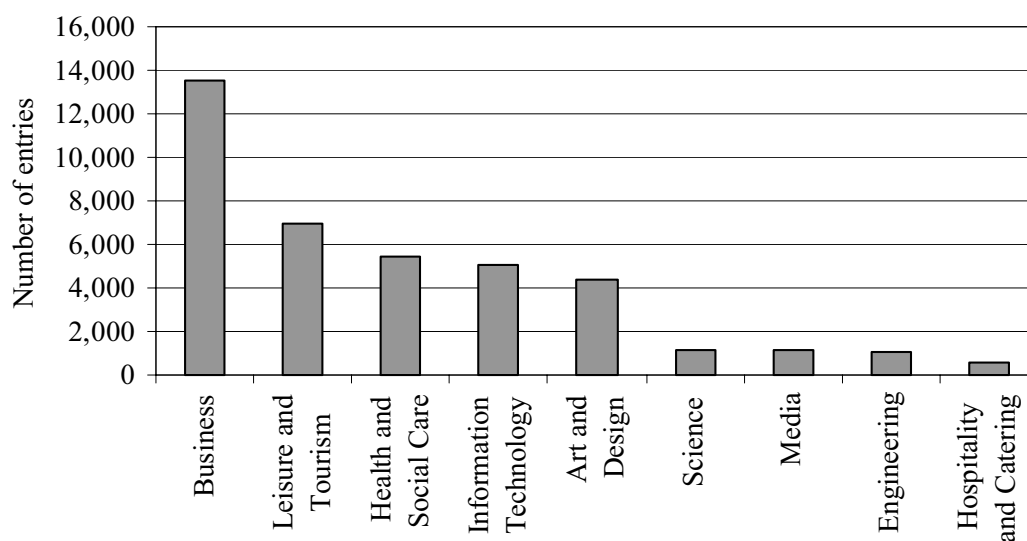


⁸ Available from www.jcgq.org.uk

⁹ Statistics of Education: Public Examinations GCSE/GNVQ and GCE/AGNVQ in England 2000. DfES. Table 19.

10. Figure A9 shows the number of candidates for all Advanced GNVQ subjects that attracted more than 500 entries in 2001. The data is for 16-18 year olds in England.¹⁰ Take-up is much lower than for traditional A levels. The total number of entries to Advanced GNVQ was 40,000, compared to almost 650,000 for A levels. Health and Social Care is the most popular science-based GNVQ with 5,472 entries. Science attracted only 1,172 entries. Although the numbers are low, they do represent a significant increase in recent years. In 1999, the Advanced GNVQ in health and social care attracted 3,149 entries, while science drew 607.

Figure A9: Graph showing the number of entries for Advanced GNVQs in 2001.



¹⁰ GCSE/GNVQ and GCE A/AS/VCE/Advanced GNVQ Examination Results 2000/2001 - England. DfES. 2002. Table 14. Available only from www.dfes.gov.uk/statistics

LIST OF ABBREVIATIONS USED IN THE REPORT AND EVIDENCE

A level	Advanced level
ABPI	Association of the British Pharmaceutical Industry
AH	Advanced Higher
ALIS	Advanced Level Information System
AQA	Assessment and Qualifications Alliance
AS level	Advanced Subsidiary Level
ASE	Association for Science Education
AVCE	Advanced Vocational Certificate of Education
BA	British Association for the Advancement of Science
BEd	Bachelor of Education
BSE	Bovine Spongiform Encephalopathy
BTEC	British Technology and Education Council
CBI	Confederation of British Industry
CEM	Curriculum Evaluation and Management
CIA	Chemical Industries Association
CITB	Construction Industry Training Board
CLEAPSS	Consortium of Local Education Authorities for the Provision of Science Services
CLRC	Central Laboratory of the Research Councils
CPD	Continuous and Professional Development
CREST	Creativity In Science and Technology
CST	Council for Science and Technology
CSYS	Certificate of Sixth Year Studies
D&T	Design and Technology
DfEE	Department for Education and Employment
DfES	Department for Education and Skills
DTI	Department of Trade and Industry
ECIA	Engineering Construction Industry Association
EEF	Engineering Employers' Federation
EMTA	National Training Organisation for Engineering Manufacture
EOC	Equal Opportunities Commission
EPSRC	Engineering and Physical Sciences Research Council
ETAN	European Technology Assessment Network
FE	Further Education
FEFC	Further Education Funding Council
FEI	Federation of the Electronics Industry
GCSE	General Certificate of Secondary Education
GNVQ	General National Vocational Qualification
HEFCW	Higher Education Funding Council for Wales
HNC	Higher National Certificate
HND	Higher National Diploma
ICT	Information and Communications Technology
IEE	Institution of Electrical Engineers
INSET	In Service Training
IT	Information Technology
ITT	Initial Teacher Training
JCQA	Joint Council for General Qualifications
LEA	Local Education Authority
LLSC	Local Learning and Skills Council
LMS	London Mathematical Society
MA	Mathematical Association
MER	Managing Environmental Resources

MMR	Measles, Mumps and Rubella [vaccine]
NCS	National Course Specification
NGFL	National Grid for Learning
NIACE	National Institute of Adult Continuing Education
NICEC	National Institute for Careers Education and Counselling
NQ	National Qualifications
NQT	Newly Qualified Teacher
NUT	National Union of Teachers
OCR	Oxford Cambridge and RSA Examinations
OECD	Organisation for Economic Cooperation and Development
OFSTED	Office for Standards in Education
OST	Office of Science and Technology
PAT	Policy Action Team
PGCE	Post Graduate Certificate of Education
PISA	Programme for International Students' Assessment
PPARC	Particle Physics and Astronomy Research Council
PSHE	Personal Social and Health Education
QCA	Qualifications and Curriculum Authority
RS	Royal Society
SAPS	Science and Plants for School
SATs	Standard Assessment Tasks
SBS	Siemens Business Service
SDA	Sex Discrimination Act
SEAS	Science and Engineering Ambassadors Scheme
SETNET	Science and Technology Network
SEU	Social Exclusion Unit
SFR	Statistical First Release
SG	Standard Grade
SHEFC	Scottish Higher Education Funding Council
SQA	Scottish Qualifications Authority
TES	Times Educational Supplement
TIMSS	Third International Maths and Science Study
UCAS	Universities and Colleges Admissions Service
UMIST	University of Manchester Institute of Science and Technology
VCE	[Advanced] Vocational Certificate of Education

PROCEEDINGS OF THE COMMITTEE RELATING TO THE REPORT

MONDAY 4 MARCH 2002

Dr Brian Iddon declared a non-pecuniary interest in relation to the inquiry into the Science Education from 14 to 19 as parliamentary liaison officer to the Royal Society of Chemistry.

WEDNESDAY 3 JULY 2002

Members present:

Dr Ian Gibson, in the Chair

Mr Tom Harris	Dr Andrew Murrison
Mr David Heath	Geraldine Smith
Mr Mark Hoban	Bob Spink
Dr Brian Iddon	Dr Desmond Turner
Mr Tony McWalter	

The Committee deliberated.

Draft Report (Science Education from 14 to 19), proposed by the Chairman, brought up and read.

Ordered, That the draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 140 read and agreed to.

Ordered, That the summary be an annex to the Report.—(*The Chairman.*)

Ordered, That the note on visits made in the course of the inquiry be an annex to the Report.—(*The Chairman*)

Ordered, That the note on international comparisons be an annex to the Report.—(*The Chairman*)

Ordered, That the statistical analysis of the take-up of science post-16 be an annex to the Report.—(*The Chairman*)

Resolved, That the Report be the Third Report of the Committee to the House.

Ordered, That the Chairman do make the Report to the House.

Ordered, That the provisions of Standing Order No. 134 (Select committees (reports)) be applied to the Report.

Several papers were ordered to be appended to the Minutes of Evidence.

Ordered, That the Appendices to the Minutes of Evidence taken before the Committee be reported to the House.—(*The Chairman.*)

Several papers were ordered to be reported to the House.

[Adjourned till Monday 8 July at Four o'clock.]

LIST OF WITNESSES

Monday 4 March 2002

Ms Georgina Day, Education Officer, the Institute of Biology; Ms Catherine Wilson, Manager for Education (Schools and Colleges), the Institute of Physics; Dr Colin Osborne, Education Manager (Schools and Colleges), the Royal Society of Chemistry; Mr Nigel Thomas, Education Manager, The Royal Society; and Ms Lucy Allen, Education Officer, the Institute of Mathematics and its Applications Ev 1

Mr Richard Shearman, Deputy Director, Engineers' Regulation, Ms Ruth Wright, Education Executive, and Mr Victor Lucas, Vocational Education and Training Advisor, the Engineering Council; Mrs Dorrie Giles, Director, Qualifications, Institution of Electrical Engineers; Mr George Salmon, Member, Education Training and Development Group, Institution of Incorporated Engineers; and Mr Chris Kirby, Professional Affairs Manager, Institution of Mechanical Engineers. Ev 11

Tuesday 19 March 2002

AT THE SCIENCE MUSEUM

Helena Perry, Quintin Kynaston School, London; Hannah Greensmith, Birkenhead High School, Wirral; and Ben Wormald, Winstanley Sixth Form College, Wigan Ev 18

Clare Dawe, Redland High School, Bristol; Tim Crocker-Buque, Worthing Sixth Form College; and Rubens Reis, St Augustine's Church of England School, London. . . . Ev 20

Anika Lewis, Colchester Sixth Form College, Charlotte Whitaker, Redland High School, Bristol; and Fern Curtis, Saint Theresa's School, Dorking Ev 21

Yasmin Akram, Sutton Coldfield Grammar School; Ashley Clarkson, Bede Sixth Form College, Teesside; Vicky Parkin Darlington QE Sixth Form College; and Christopher Gascoyne, Ecclesbourne School, Derbyshire. Ev 23

Joel Brown, Dixons City Technology College, Bradford; Lexi Boyce, Long Road Sixth Form College, Cambridge; Mark Towers, Farnborough Sixth Form College; Sam Ford, Ermysted's Grammar School, Skipton; and Karl Stringer, Worthing Sixth Form College. Ev 25

Kayleigh Goddard, Shrewsbury High School; Lucy Ferguson, Guildford High School; Ashwin Reddy, Bedford School; and Sajad Al-Hairi, North Westminster Community School. Ev 27

Monday 25 March 2002

Ms Michelle Ryan, Ricards Lodge High School, Wimbledon; Mr James Salmon, Anglo-European School, Essex; Ms Corinne Stevenson, Hounslow Local Education Authority; and Ms Hannah Strange, Notting Hill & Ealing High School Ev 30

Mr Mike Collins, Hengrove School, Bristol; Ms Sylvia Thomas, Darlaston Community School, Walsall; Dr Susan Turner, Bishop David Brown School, Woking; and Mr Ed Walsh, Roseland Community School, Truro Ev 34

Ms Catherine Crocker, Esher Sixth Form College; Surrey, Ms Gillian Halton Institute of Education, Manchester Metro University; Mr Chris Peel, City and Islington Sixth Form College, CLEAPSS School Science Service; and Ms Jean Skeggs, Hertfordshire LEA Ev 37

Ms Jane Clifford, Brooklands College, Surrey; and Mr Chris Roberts, Bradford College Ev 41

Dr David Moore, Chief Executive, and Mr Derek Bell, Past Chair, Association for Science Education; and Ms Judith Norrington, Director of Curriculum and Quality, and Ms Maggie Scott, Curriculum and Quality Adviser, Association of Colleges Ev 44

Monday 15 April 2002

Ralph Levinson, Institute of Education, University of London; Clare Matterson, The Wellcome Trust; Dr Jerry Ravetz; and Dr Jon Turney, University College London . . Ev 49

Dr Stuart Brown, Nottingham Medical School, Professor Ian Haines, UK Deans of Science Committee (Faculty of Science, Computing and Engineering, University of North London); and Professor Tom Ruxton, Engineering Professors' Council (School of Engineering and Advanced Technology, Staffordshire University) Ev 54

Ms Vicki Garson, Association of the British Pharmaceutical Industry (UK Human Resources Director, Training and Development, AstraZeneca); Mr Alan Hanslip, Vice President, Human Resources, Octel Corp., Mr Graham Speechley, Managing Director, Benteler Automotive UK; and Ms Erica Tyson, Engineering Training Manager, Rolls-Royce Ev 59

Monday 29 April 2002

Keith Weller, Head of Qualifications Division, and Martin Hollins, Principal Officer for Science, Qualifications and Curriculum Authority; David Barrett, Director for General Assessment, OCR, and John Mitchell, Director, Education and Research, AQA, Joint Council for General Qualifications Ev 65

Stephen Timms MP, Minister of State for School Standards, and Janet Dallas, Team Leader for Science and Technology Strategy within the Curriculum Division, Department for Education and Skills Ev 73

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LIST OF UNPRINTED EVIDENCE

Additional written evidence has been received from the following and has been reported to the House, but to save printing costs it has not been printed and copies have been placed in the House of Commons Library where it may be inspected by Members. Other copies are in the Record Office, House of Lords, and are available to the public for inspection. Requests for inspection should be addressed to the Parliamentary Archives, Record Office, House of Lords, London, SW1A 0PW(Tel 020 7219 3074). Hours of inspection are from 9.30 am-5.30pm on Mondays to Fridays.

African-Caribbean Network for Science and Technology (extract - SED 14)
 Dr Eric Albone, Clifton Scientific Trust (SED 77)
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 The BA (annex - SED 29)
 Centre for Science Education, Sheffield Hallam University (SED 26)
 Michael Coldbeck (SED 101)
 Mike Collins (SED 65)
 Catherine Crocker (SED 58)
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 Dr A Gardiner (SED 23)
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 Donald Hindson (SED 52)
 Martin Lanyon (SED 16)
 Professor John Leach (SED 1)
 Brian Lumsden, Merck Sharp & Dohne Ltd (SED 75)
 Christine Marshall (SED 61)
 Brian Matthews, (SED 12)
 Phil Millington (SED 73)
 Mary Munro, National Institute for Careers Education and Counselling (SED 6)
 Professor Denis J Murphy (SED 83)
 National Space Centre (SED 17)
 Chris Peel (SED 60)
 M M Penn (SED 53)
 Qualifications and Curriculum Authority (appendices - SED 42 and supplementary Memorandum SED 98)
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Ed Walsh (SED 63)
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The Wellcome Trust (annex - SED 27)
WISE (Women in Science and Engineering) (SED 55)
Robert Worley (SED 50)

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