

HOUSE OF LORDS

Science and Technology Committee

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10th Report of Session 2005–06

# Science Teaching in Schools

Report with Evidence

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*Mr John Bangs, Assistant Secretary (Education and Equal Opportunities), National Union of Teachers (NUT); Ms Elspeth Farrar, Director, Careers Advisory Service, Imperial College London; Ms Marie-Noëlle Barton, Director, Women into Science, Engineering and Construction (WISE)*

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*Dr Michael Day, Executive Director of Initial Teacher Training, Dr Stephen Baker, TDA Strategy, Training and Development Agency for Schools; Dr Derek Bell, Chief Executive, Association for Science Education (ASE); Mr Phil Bunyan, Director, Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS)*

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## **ABSTRACT**

Effective science teaching in schools is essential, both for ensuring a satisfactory degree of scientific literacy in society at large, and for equipping the next generation of scientists and engineers to progress into higher education and beyond. In this report, we seek to show how the examination system and the provision of advice to students can be improved; how science and mathematics teaching can be enhanced and enriched; how the current problems with teacher recruitment and retention can be tackled; and how the take-up and provision of continuing professional development (CPD) can be addressed.

There is good evidence that students are opting for “easier” A-levels over the sciences and mathematics. This problem is compounded by the fact that students are being forced to study an excessively narrow range of subjects at too early an age. The Government should replace A-levels over the long-term with a broader-based syllabus for post-16 students. To this end, we recommend that the Government both revisit Sir Mike Tomlinson’s proposals for a broader diploma system for 14–19 students and give further consideration to the International Baccalaureate. These systems would ensure that students receive a more rounded education and do not over-specialise before they have seen the merits of pursuing science and mathematics. We also call for the Government to improve the quality of careers advice in schools as a matter of urgency.

We are deeply concerned about the impact that so-called “teaching to the test” is having upon the quality of science and mathematics teaching. We therefore call on the Government to alter the current testing regime so that the tests assess a much broader range of skills, thus allowing teachers greater flexibility to inspire students in the classroom. In particular, we believe that the Government must act to secure the future of practical science in schools. We call for a central website on practical science to help address health and safety fears, and urge the Government to improve their unsatisfactory “exemplar” designs for science laboratories by consulting much more widely with experts in the field. Finally, we recommend a proper career structure and improved pay for school science technicians, who continue to be undervalued in spite of the crucial role they play.

There is a serious shortage of specialist physics and chemistry teachers, which is a barrier to better teaching of these subjects. We strongly believe that this issue can only be tackled effectively if schools are given more freedom to offer significantly higher salaries to candidates with specialist qualifications in these subjects: market forces cannot be ignored. We also call for the Government to offer longer-term incentives to science and mathematics teachers, by reducing the size of the golden hellos and offering to write off student debts in return for four or five years’ service. Finally, we call for a better-paid and faster route for those people with substantial expertise of science or mathematics in industry to gain qualified teacher status.

On professional development, we recommend that the Government make it compulsory for teachers to undergo a certain amount of subject-specific CPD each year. We also call for additional ring-fenced money to be allocated to schools in order to cover the cost of supply teachers standing in for staff on CPD courses.

# Science Teaching in Schools

## CHAPTER 1: INTRODUCTION

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- 1.1. Good science teaching in schools is fundamental to the relationship between science and society as a whole. This became clear to us when, in 1999–2000, we conducted the major inquiry that resulted in our 2000 report *Science and Society*.<sup>1</sup> Even though we chose not to focus on education in that inquiry, its importance was so clear that we simply could not ignore it. We not only devoted a chapter in that report to science education, but shortly thereafter initiated the short inquiry that led to our 2001 report *Science in Schools*.<sup>2</sup>
- 1.2. In both these reports we argued for a high and consistent standard of continuing professional development for science teachers, and for more and better quality practical work within science teaching. These two issues remain crucial to improving the motivation of science teachers, raising the quality of teaching, and thus to engaging young people with science.
- 1.3. Since 2001, the Government have displayed an impressive determination to improve the teaching of science and mathematics and to engage students more effectively in these subjects. In particular, *Science and innovation investment framework 2004–2014: next steps*, published in March 2006, set out ambitious targets to increase the number of students taking A-levels in physics, chemistry and mathematics, and the number of teachers specialising in those subjects. However, the decline in the number of students sitting A-level physics has continued apace, and there remains a shortage of specialist chemistry and physics teachers. Clearly more needs to be done.
- 1.4. As recently as September, the newly-formed Science Community Partnership Supporting Education (SCORE) partnership warned that “the next generation of scientists could be lost if urgent, concerted action is not taken”. The partnership, which brings together the scientific learned societies, the Science Council and the Association for Science Education, will focus in particular on the two issues mentioned above: the low take-up of physics A-level and the shortage of specialist chemistry and physics teachers. It aims to do this by providing the Government with “a coherent voice from the scientific community, advising on how to best address some of the key issues facing science education”.<sup>3</sup>
- 1.5. This is therefore a timely opportunity to revisit the themes of our previous reports, focusing on the take-up of science and mathematics at GCSE and beyond, teaching methods, the recruitment and retention of teachers, and the role of continuing professional development for teachers. In so doing, we have opted to focus on secondary education in England, although we acknowledge the great importance of quality science and mathematics teaching in primary schools. We have not looked in detail at the science curriculum, which has only just been reviewed at GCSE level, partly in

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<sup>1</sup> House of Lords Science and Technology Committee, Third Report of Session 1999–2000, *Science and Society* (HL Paper 38).

<sup>2</sup> House of Lords Science and Technology Committee, First Report of Session 2000–01, *Science in Schools* (HL Paper 49).

<sup>3</sup> See <http://www.royalsoc.ac.uk/news.asp?id=5215> and <http://www.royalsoc.ac.uk/page.asp?id=5216>.

response to the 2002 report by our sister Committee in the House of Commons, *Science Education from 14 to 19*.<sup>4</sup>

### **Acknowledgements**

- 1.6. We received valuable written and oral evidence from the witnesses listed in Appendix 2, for which we are most grateful. In addition, we thank those who took part in our seminar at the House of Lords on 14 June 2006.
- 1.7. We are also indebted to those who made our visits to the National Science Learning Centre, Huntington School, York and Little Heath School, Reading so successful.

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<sup>4</sup> House of Commons Science and Technology Committee, Third Report of Session 2001–02, *Science Education from 14 to 19* (HC Paper 508).



## CHAPTER 2: STUDENT ATTITUDES AND CHOICES

- 2.1. The attitudes of students towards science and mathematics, and the choices that they make as a consequence, are absolutely central to the issues which this report seeks to address. The more positive the opinions of students towards science and mathematics, the more likely they are to opt for these subjects at GCSE and beyond, and to pursue them at further or higher education level. This in turn will lead to more of them pursuing STEM careers.
- 2.2. The remaining chapters of this report examine issues which all ultimately impact upon the formulation of student attitudes towards science and mathematics throughout their years of secondary education. In this chapter, we focus more narrowly on the number of students studying science and mathematics beyond GCSE, the factors which influence their choice of subject (including the broad question of the nature of the A-level system), the Government's targets in this area and the role that careers advice can play.

### Background

- 2.3. The data on A-level entries over the last ten years are mixed. The table below sets out the figures.

**TABLE 1**

#### A level entries for science and mathematics in schools and colleges

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
<b>Biology</b>	43,398	47,807	48,897	47,192	46,190	44,592	45,407	43,902	44,235	45,664
<b>Chemistry</b>	34,677	36,613	37,103	35,831	35,290	33,871	32,324	31,065	32,130	33,164
<b>Physics</b>	28,400	28,903	29,672	29,552	28,191	28,031	27,860	26,278	24,606	24,094
<b>Other science</b>	4,194	4,301	4,325	4,124	3,834	3,587	3,740	4,029	3,773	3,779
<b>Mathematics</b>	54,125	56,050	56,589	56,100	53,674	54,157	44,156	44,453	46,017	46,037
<b>Further mathematics</b>	4,913	4,999	5,211	5,145	5,015	5,063	4,498	4,730	5,111	5,192

Source: DfES<sup>5</sup>

- 2.4. It is encouraging that the number of students taking biology is increasing, following a decline between 1998 and 2001. The figures for chemistry, mathematics and further mathematics are less healthy. Whilst the numbers for all three have started to rise in the last few years, they remain considerably lower than they were in the late 1990s and the increase should in any case be seen in the context of an overall rise in total A-level entries. Clearly, it is essential that no further decline takes place. The most problematic subject of all is physics, with the number of students opting to take the subject showing a precipitous fall since 1998. The numbers continue to fall and currently stand at less than 60 per cent of the total in the late 1980s. Moreover, the situation is far worse in some schools than these

<sup>5</sup> These figures only cover those students taking the A-levels at the age of 18 in England. The 2006 figures were not available in this format at the time of writing.

aggregated figures would suggest—as the Royal Society noted, “science take-up is strongly skewed at present, with half of all A-level entries in science coming from just 18 per cent of schools” (p 63).

- 2.5. The Government have set some ambitious targets to increase the numbers of students taking science and mathematics A-levels. By 2014, it is hoped that entries to A-level physics will have increased to 35,000 (currently 24,094), entries to chemistry to 37,000 (currently 33,164) and entries to mathematics to 56,000 (currently 46,037) (p 2). The Government recognised that it would be “very challenging” to reach these targets, both because of the pattern of decline mentioned above and because of the predicted decline in cohort size, which means that there will need to be “an even larger increase in the proportion of pupils who continue to study A-level science” than would be required if the cohort remained at its current size (p 3).
- 2.6. In oral evidence, Lord Adonis, Parliamentary Under-Secretary of State for Education, accepted that these ambitions were not “precise targets based on very advanced forecasting techniques”, but felt that it was reasonable “to set a target over the next eight years to restore the position to broadly that which applied in the early to mid-1990s” (Q 4). However, he reiterated that “these are ambitious targets” and noted that the targets for physics A-level entries were “the most ambitious by some way” given the continuing decline in numbers (Q 5).
- 2.7. The Government’s targets were generally welcomed. However, the *Next Steps* document is thin on what needs to be done if they are to be met. As Daniel Sandford Smith of the Institute of Physics said, “we would like to see more about how that ambition is going to be realised” (Q 99). We therefore seek below to identify some of the reasons behind the declining numbers of recent years and to pinpoint the actions that need to be taken in the coming years in order to increase the number of students studying science and mathematics beyond GCSE.

### **Factors affecting post-GCSE choices**

- 2.8. It is difficult to analyse the A-level trends with any great confidence. As Research Councils UK pointed out, “the decline in the numbers of students studying these subjects is a very complex process which is not accessible to simple solutions. In particular, the factors affecting students’ choice of subject ... are numerous, and their interactions are not well-understood” (p 197). However, several issues emerged repeatedly in the evidence.
- 2.9. One such issue is essentially fashion—in particular, the emergence of new subjects that have only become available at A-level in recent years, such as psychology, media studies and photography. As Marie-Noëlle Barton of Women into Science, Engineering and Construction (WISE) noted, “there is now a huge array of A-levels available and a lot of young people choose what they call the ‘funky’ subjects” (Q 151). We do not denigrate these subjects, but some—for instance psychology, which is a science in its own right—have clearly drawn students away from the traditional sciences. Indeed, as the British Psychological Society pointed out, over 50,000 students sat the psychology A-level in 2005, which is significantly more than sat physics or chemistry (p 139).
- 2.10. An inevitable consequence is the dilution of the science A-level combinations for which able science students have traditionally opted. Professor Margaret

Brown of the Advisory Committee on Mathematics Education (ACME) told us that the introduction of a wider choice of A-levels had had “quite a dramatic effect in reducing the number of students doing the normal offering of mathematics / physics / chemistry or mathematics / chemistry / biology which is down to 60 per cent of what it was in 2001” (Q 109). However, even if it were desirable to do so, it would be very difficult to reverse the introduction of a greater choice of A-level subjects; as Professor Brown said, “once you have let the genie out of the bottle, I think it is quite hard to say to students that last year’s students were allowed a free range of choice and you are not” (Q 113). We agree.

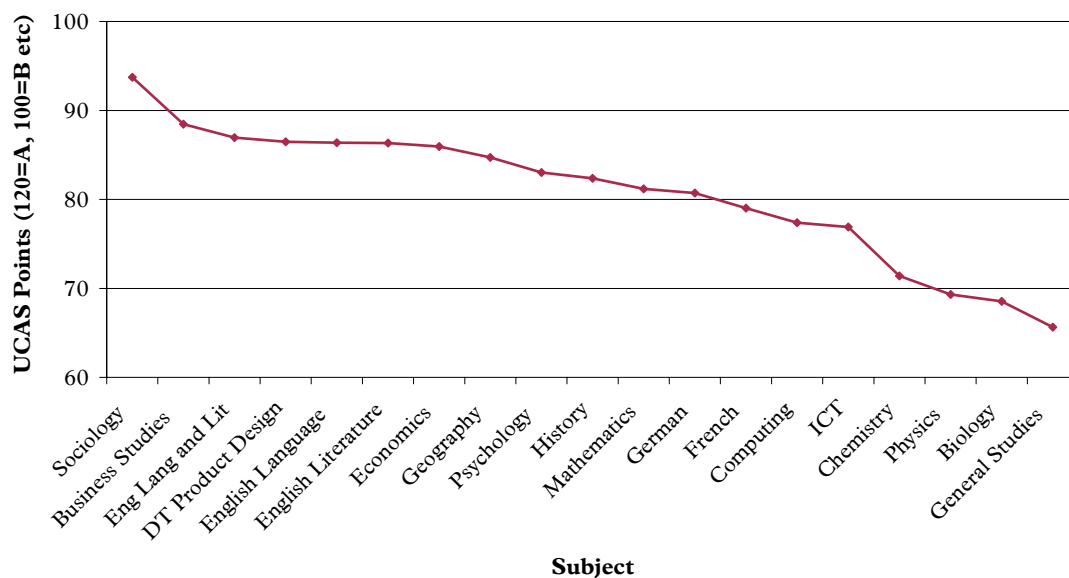
- 2.11. The traditional sciences and mathematics need not feel threatened by the broader range of A-levels available, but it is essential that students should perceive them in the best possible light. One problem here is that science and mathematics can be portrayed as boring or irrelevant to modern life. This partly relates to the content of the specifications, but even more important is the style and quality of the teaching. As the written evidence from the Science Learning Centres stated, “inspired teaching is the key to inspiring young people towards the continued study of science” (p 173).
- 2.12. It was suggested to us that poor teaching affects female students in particular, who are seriously under-represented in the physical science A-levels. The Institute of Physics argued that “girls are much more likely than boys to be deterred by poor and uninspiring teachers” (p 57). Similarly, Marie-Noëlle Barton of WISE told us that “girls are particularly sensitive to what happens in the classroom” and emphasised the importance of “gender-free” examples in science teaching (Q 151). The importance of specification content and good science teaching are addressed in more detail in Chapters 3 and 4.
- 2.13. A more serious and fundamental problem is the perception that the traditional science subjects and mathematics are more difficult than other subjects, and that it is consequently more difficult to achieve impressive A-level grades—a point that was made forcefully by the students with whom we spoke at Huntington School in York. Marie-Noëlle Barton felt that this was particularly true of physics: “it is perceived by young people, it is perceived by a lot of teachers (and I am not talking about the science teachers but other teachers), it is perceived by the parents as being a difficult subject” (Q 151).
- 2.14. Again, it was suggested that the perception that sciences are difficult affected female students disproportionately—the Institute of Physics claimed that girls were particularly liable to feel that physics was “too difficult and not for them”, another cause of their under-representation at physics A-level (p 57). There is also a risk that state school students and their teachers are more likely to be deterred by perceived difficulty than their contemporaries at private schools, which could result in an unhealthy social distortion in the science field. We have already drawn attention to the fact that half of all A-level science entries come from 18 per cent of schools.
- 2.15. This issue of relative difficulty has profound implications. On the one hand, as the Royal Meteorological Society noted, “students looking forward to university entrance will be strongly motivated by what they perceive to be their best chance of obtaining the necessary A-level grades” (p 209). Similarly, Dr Colin Osborne of the Royal Society of Chemistry told us that students “realise they have to get a certain number of points to go to

university, so often they choose to take subjects that are perceived to be (and indeed may be) easier” (Q 105).

- 2.16. On the other hand, schools, in seeking to improve their position in competitive league tables, may be tempted to maximise A-level scores by encouraging students to choose easier subjects. The Institute of Physics reported anecdotal evidence of schools “actively discouraging students from taking subjects that could weaken their league table position” through lower A-level grades (p 57). If these perceptions are well-founded, they throw into question the A-level “gold standard” on which post-16 education is currently based.
- 2.17. Analysis of A-level results does in fact suggest that science and mathematics are more difficult than other subjects at A-level. The figures below, based on very large samples, have been produced by the Curriculum, Evaluation and Management (CEM) Centre at Durham University. Figure 1 shows the predicted A-level grades in a variety of different subjects for a student with an average GCSE grade B—the pattern is similar for students with different grade averages—and suggests that the three sciences are some of the hardest subjects. Figure 2 embodies a different approach, a complex comparative formula which looks at the relationship between each grade achieved by each individual student and the grades that the same student scored in his or her other subjects. Following an iterative process, a “relative grade” is produced for each subject. Essentially, the higher the relative grade, the more difficult the subject. Again, the sciences and mathematics are amongst the most difficult of all subjects.

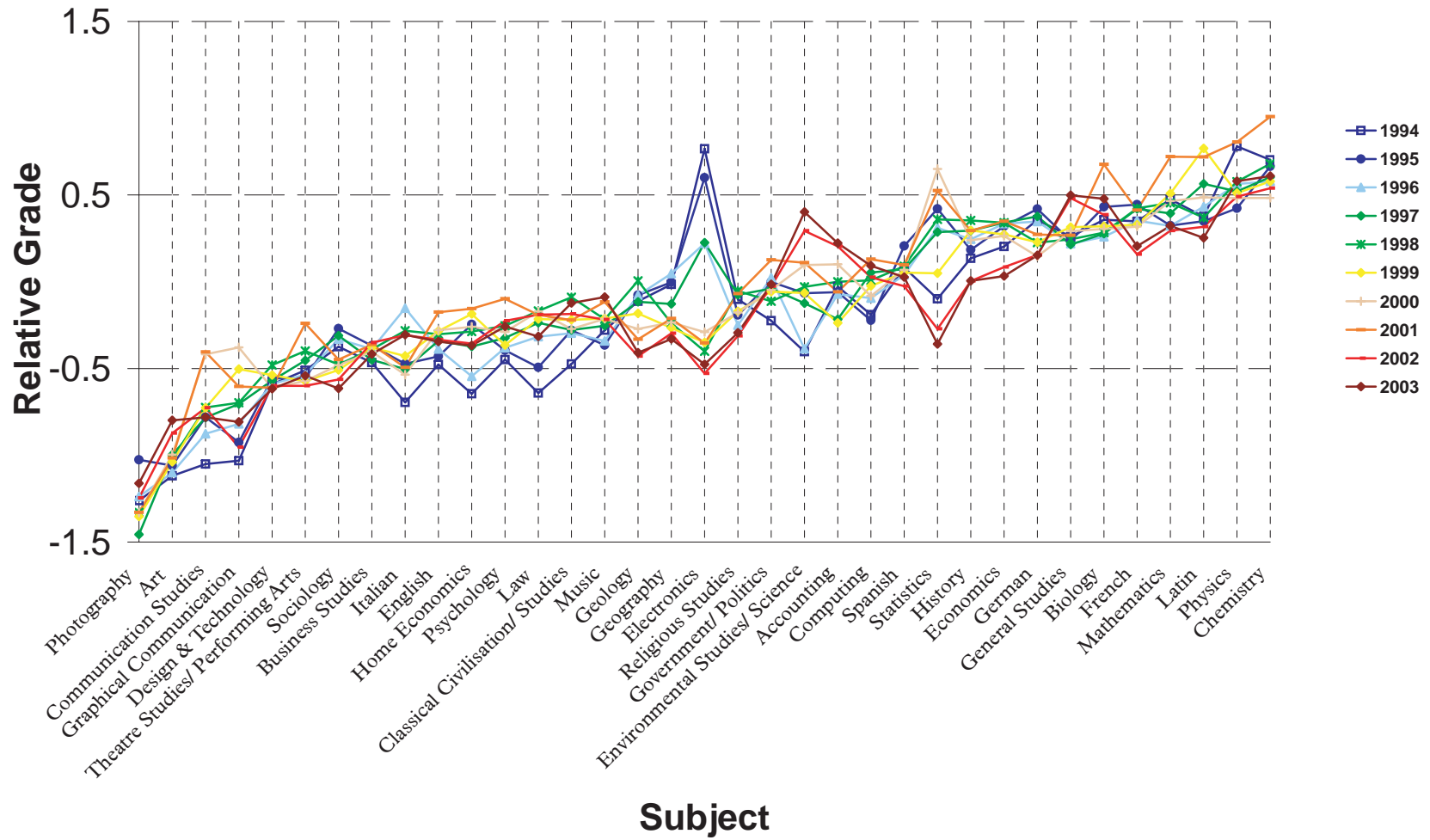
**FIGURE 1**

**Expected A-Level Grade(as points) of a student with an average GCSE Grade B**



Source: CEM Centre, Durham University

**FIGURE 2**  
**ALIS Project: A Level subject relative difficulties**



Source:CEM Centre, Durham University



- 2.18. The CEM Centre's methodology is widely if not universally accepted. It produces similar findings each year which are broadly consistent with data produced using alternative systems. However, when we asked the Government to respond to these tables, we were told that "the DfES and the QCA have always responded to such claims by stating that there is no such thing as an easy or hard A-level. In terms of UCAS tariff points etc all A-levels are weighted equally. We have no plans to move from this position".<sup>6</sup> This is an unconvincing response. The fact that equivalent grades in all A-level subjects are worth the same number of UCAS points, regardless of difficulty, goes to the very heart of the problem.
- 2.19. Students studying science and mathematics thus appear to face an in-built disadvantage because, in general, more hard work and/or ability are needed to achieve the same number of UCAS points as might more readily be achieved in most other subjects. Clearly, higher education institutions and employers should be able to distinguish between an "A" in physics and an "A" in photography, for example. Indeed, Cambridge University has drawn up a list of A-levels which "provide a less effective preparation for our courses"—including Business Studies and Media Studies—and advised students that they should take at least two "traditional academic subjects" (i.e. those not on the list).<sup>7</sup> However, students may still be deterred from taking the more difficult A-levels because of their desire to achieve as impressive a set of A-level grades as possible.
- 2.20. This is not a problem with an easy solution, which is probably why, in the words of the Royal Society of Chemistry, "the QCA has addressed the issue of standards over time but has not addressed the issue of cross-subject comparability" (p 48). Although the QCA does profess to look at cross-subject comparability, it does not appear thus far to have taken solid action in light of any findings.<sup>8</sup> This is a major problem and clearly needs to be taken more seriously by both the Government and the QCA.
- 2.21. In terms of a remedy, Professor Brown of ACME said, "I think there is a temptation to say that we dumb the subjects down and that is clearly what we must not do" (Q 103). We firmly agree that "dumbing down" is out of the question—standards must be maintained. Dr Osborne of the Royal Society of Chemistry echoed these sentiments, commenting, "I am not suggesting either that we should be dumbing down the sciences or mathematics. What I am suggesting is that perhaps some of these other subjects should be made harder, which would not be a difficult task but would be remarkably unpopular" (Q 105). However, whilst it might appear desirable to seek a common standard across all subjects, it would in reality be a difficult if not impossible task to align all A-level subjects with one single arbitrary level of difficulty. Difficulty means different things in different subjects, reflecting the various skills and faculties required of students. Moreover, the growing number of A-level choices open to students means that accepted, traditional tests of difficulty have to adapt to an increasingly complex and diverse environment.
- 2.22. One possibility might be for UCAS or higher education institutions themselves to extend the approach already in effect adopted by Cambridge

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<sup>6</sup> Written evidence (not published).

<sup>7</sup> See <http://www.cam.ac.uk/admissions/undergraduate/requirements>.

<sup>8</sup> See [http://www.qca.org.uk/3657\\_7153.html](http://www.qca.org.uk/3657_7153.html).

University, and to weight different A-levels so that, for example, an “A” grade at physics A-level is worth more points than the same grade at photography A-level. However, agreeing criteria for establishing which subjects are harder—and therefore should be worth more points—would be difficult if not impossible, and could artificially distort students’ A-level choices towards subjects to which they are not so well suited. Moreover, such an approach could potentially put them at an unfair disadvantage when seeking employment.

- 2.23. Nor would the re-introduction of grade quotas solve this problem—indeed, it would probably exacerbate it. Although the sciences and mathematics appear to be amongst the “hardest” of A-levels, the percentage of students achieving A grades in them is generally higher than in other “easier” subjects.<sup>9</sup> This is largely because the “harder” subjects tend to be sat by higher ability students, although there are other relevant factors. Therefore, the introduction of quotas could mean *fewer* “A” grades in the sciences and mathematics, and *more* in the easier subjects, which would clearly not be a desirable outcome.
- 2.24. What these issues demonstrate is that the “gold standard” of A-levels is now fundamentally compromised. The presumption that an A-level “A” grade represents a fixed level of achievement (embodied in an equal UCAS tariff) is hard to defend. An alternative way to ensure that the assessment system is an accurate reflection of ability might be to replace A-levels with a baccalaureate or broad-based system of diplomas, ensuring that everybody is examined on a mixture of “difficult” and “easy” subjects.
- 2.25. This proposal is in line with the 2004 report of Sir Mike Tomlinson’s Working Group on 14–19 Reform,<sup>10</sup> which recommended the development of a broad-based system of diplomas, available at entry, foundation, intermediate and advanced levels, which would ultimately replace GCSEs, A-levels and NVQs. Such a system would not only go a long way towards solving the issue of cross-subject comparability, it would also ensure that students left school with a broader and more well-rounded education.
- 2.26. Whilst the Tomlinson Report is wider in scope than this inquiry, its central recommendation chimes with the concerns we have heard that students are being forced to narrow their areas of study at too early an age. When the perception that some subjects are “easier” than others is factored in, the result is that students are in many cases giving up science and mathematics before they can fully appreciate the opportunities that qualifications in these subjects can bring. Professor Martin Taylor of the Royal Society said, “our current A-level system, when it asks people to choose three A-levels, is implicitly asking them to choose away from an awful lot of other things”. He added, “the Tomlinson Report had started to look for some flexibility there, maybe a diploma system, maybe something like a baccalaureate system, something that was wider and left children up to the age of 18 not having rejected so many things. I think that would be quite welcome” (Q 108).
- 2.27. We agree with the Royal Society. The Tomlinson Report made a convincing case for replacing A-levels with a diploma system. In response, the

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<sup>9</sup> For example, see <http://www.icq.org.uk/attachments/published/285/1/A-Level%20Results%20Booklet%202006%20Password%20Protected.pdf>.

<sup>10</sup> DfES, *14-19 Curriculum and Qualifications Reform: Final Report of the Working Group on 14-19 Reform*, October 2004.

Government's White Paper on 14–19 Education and Skills stated that “we understand and appreciate the argument that we should challenge our A-level students further, by demanding more breadth. But there is no clear consensus amongst pupils, parents, employers or universities on whether and how it should be done”.<sup>11</sup> This response ducks the central issue. It is time the Government showed strong leadership.

- 2.28. **There is good evidence that students are opting for “easier” A-levels over the sciences and mathematics, a problem which is compounded by the specialisation forced upon students by the A-level system. We call on the Government to replace A-levels, over the long-term, with a broader-based syllabus for post-16 students. To this end, we suggest that they revisit Sir Mike Tomlinson’s proposals for a diploma system and also consider the International Baccalaureate Diploma Programme. These systems would allow students to maintain greater breadth in their studies, giving them more time to choose the areas which they wish to pursue. They would also result in a more rounded education and would prevent the damage caused by the perception that science and mathematics A-levels are particularly difficult.**

### Importance of high-quality advice

- 2.29. As long as the A-level system remains in operation, it is essential that students should receive top quality advice about the significant benefits of studying the sciences and mathematics. There is clearly some way to go if this goal is to be achieved, however; as SETNET (The Science, Engineering, Technology and Mathematics Network) noted, “a significant influence on this decline [in science A-level entries] is an insufficiently wide understanding of the breadth and excitement of the careers that can be pursued with science, technology, engineering and mathematics qualifications” (p 215). The Royal Astronomical Society commented, “most young people have no idea what a scientist actually does, apart from possibly doctors, vets, and more recently forensic scientists (from television dramas and documentaries)” (p 204).
- 2.30. The key to ensuring that students are fully informed about the different types of STEM careers before they choose their A-level subjects is high quality school careers advice, from both careers advisers and science teachers themselves. The Institute of Physics (IoP) had serious concerns in this regard, claiming that “students are not being given accurate careers advice at a sufficiently early age to allow them to make informed choices ... careers advice tends to be reactive and does not give students a full picture of the consequences of subject choices” (p 58). Similarly, SETNET complained that careers advice was “inadequate and often stereotypical” (p 215).
- 2.31. Drawing on a report conducted in 2000, the IoP noted that science teachers did not see themselves as a source of advice because they did not feel able “to keep up with careers information” (p 58) and the Science Learning Centres added that there should be “better careers information available to science teachers, who are often the people to whom students ... turn first when considering whether to opt for science subjects” (p 179).

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<sup>11</sup> DfES, *14-19 Education and Skills—White Paper*, February 2005, p 6.



- 2.32. Careers advisers, meanwhile, overwhelmingly had humanities or social science backgrounds—the IoP noted that just one in ten of those surveyed had science degrees (p 58). The consequences of this imbalance were illustrated by a study, highlighted by Marie-Noëlle Barton, which showed that “90 per cent of careers advisers ... did not feel confident with giving advice about science and engineering careers” (Q 146). Similarly, Daniel Sandford Smith of the IoP referred to “horror stories of careers advisers advising students not to do the sciences because they are more difficult” (Q 108).
- 2.33. Elspeth Farrar, Director of the Careers Advisory Service at Imperial College London, made a more general point about the quality of careers advice offered at school: “the advice that [is] given to the more able students in schools now, particularly those that are staying on to do A-levels and thinking about carrying on into university, is not as good as it has been in the past”. She felt that this was related to the introduction of the Connexions Service which “very much had its priorities around the less able students” at the expense of more able students. She concluded, “I think this has had some effect on their guidance on going into university, their choice of subjects and maybe not having as much of a scope or a breadth of ideas about what they could go on and study as they maybe had in the past” (Q 146).
- 2.34. These comments were endorsed by Marie-Noëlle Barton of WISE, which works to increase the number of women going into STEM careers. She suggested that “it is almost now a stigma for young people to go and see a careers adviser from the Connexions Service, because they deal mainly with young people who have got drugs problems and so on” (Q 146).
- 2.35. The importance of improving the provision of quality information on science and engineering careers was recognised in Sir Gareth Roberts’ seminal 2002 review, *SET for success: the supply of people with science, technology, engineering and mathematics skills*. The review recommended that “the Government establish a small central team of advisers—possibly within the new Connexions service—to support existing advisers, teachers and parents in making pupils aware of the full range of opportunities and rewards opened up by studying science, mathematics and engineering subjects”. It also called on the Government to “review, in three years’ time, the progress in improving pupils’ knowledge of the rewards and the breadth of careers arising from studying science and engineering, and take further action as necessary”.<sup>12</sup>
- 2.36. The Government initially responded to this recommendation by pledging to “establish a team that can help Connexions Personal Advisers and teachers in offering such careers advice [on science and engineering]”. However, when we followed up this commitment, the department showed considerable confusion as to whether the necessary action had indeed been taken. Eventually, we were told that “the Government did not establish a specific team within Connexions” because it was important for the service to offer “impartial advice reflecting individual need”. Instead, the department pointed to its work with the Science, Engineering, Manufacturing

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<sup>12</sup> HM Treasury, *SET for success: the supply of people with science, technology, engineering and mathematics skills*, April 2002, p 80.

Technologies Alliance (SEMTA), the role of the “jobs4u” careers database and several assorted resources.<sup>13</sup> This is simply not sufficient.

- 2.37. When questioned about the state of careers advice during oral evidence, the Schools Minister, Jim Knight MP, accepted that “people have this notion that science careers are being a scientist or being a doctor and they are not seeing the full range and excitement of things which you can then go on to do with science A-levels and science degrees”. However, his own explanation of the Government’s response to this problem was vague, and showed little sense of urgency: “we are currently having some discussion around how we can develop information advice and guidance as part of the 14 to 19 changes which we are implementing over the next seven years” (Q 9).
- 2.38. Other witnesses were unimpressed with the progress made by the Government in this area. The IoP felt that “the DfES does not seem to have taken any steps to address these issues” (p 58). SETNET commented, “we felt that the lack of any mention in *Next Steps* of how the provision of careers information is to be improved and made into a really effective tool to help increase the interest of young people in studying science subjects, was a significant gap. We are keen that this is not overlooked or sidelined” (p 216).
- 2.39. A potentially invaluable new initiative to improve the flow of STEM careers advice to students is the proposed “Careers from Science” website, which is being put together under the auspices of the Science Council. As the Chief Executive of the Science Council, Diana Garnham, told us, the website “will have sections for teachers, careers advisers and parents ... [it] will build an awareness of the skills studying science develops, how options are kept open by studying science and it aims to ensure that students have the right information to hand when choosing subject combinations”. Vitaly, it is a collaborative initiative which will “provide an accurate picture of the entire STEM landscape and the possibilities it can offer rather than reflecting a particular organisation’s chosen message”.<sup>14</sup>
- 2.40. Currently, a little less than one half of the required funding has been raised, with contributions received from the Royal Society, the Institute of Physics and the Royal Society of Chemistry, among others. A project manager has also been appointed. Yet, even though considerably more funding is required, the Government appear to have failed to live up to their commitment to “work with the Science Council on developing a science careers website”.<sup>15</sup> The Royal Society of Chemistry complained that the Government had “failed to offer any support to realise this project” (p 48) and Diana Garnham warned, “we consider that partnership with DfES is crucial to the success of the project and indeed, a funding partnership with Government is critical for us to secure the financial commitments already made”.<sup>16</sup>
- 2.41. **In general, the Science, Technology, Engineering and Mathematics (STEM) careers advice offered in schools appears not to be of sufficient quality, and the Connexions Service is not well adapted to the needs of high achieving students. The Government have largely**

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<sup>13</sup> Written evidence (not published).

<sup>14</sup> Written evidence (not published).

<sup>15</sup> HM Treasury, *Science and innovation investment framework 2004-2014*, July 2004, p 91.

<sup>16</sup> Written evidence (not published).

**neglected careers advice in *Next Steps*, and this omission should be remedied at the earliest opportunity. We recommend that the Government act upon the findings of the Roberts Review by establishing a small central team of advisers to support existing advisers, teachers and parents in making pupils aware of the full range of opportunities and rewards opened up by studying science, mathematics and engineering subjects.**

- 2.42. The proposed “Careers from Science” website would be a valuable tool in persuading more students to study STEM subjects at A-level and beyond. In light of earlier commitments, the lack of Government assistance to the Science Council is unacceptable. We urge the Government to provide financial and logistical support to the project as a matter of urgency.**

### CHAPTER 3: TEACHING METHODS

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- 3.1. Good teaching is key to persuading students to continue studying science and mathematics to GCSE, A-level and beyond, as discussed in Chapter 2. It is also of central importance in ensuring that those students who choose not to continue in these fields have a sufficient grasp of science and mathematics to enable them to prosper in their future lives.
- 3.2. In this chapter we consider the ways in which science and mathematics are taught, encompassing both content and the ways in which that content is imparted. This includes specification content, the effects of testing, the involvement of industry, the use of external resources and the role of practical work in school science.

#### The evidence base

- 3.3. First, though, it is necessary to consider the ways in which science teaching in schools is monitored. Both the Government and the array of other organisations working towards excellence in science teaching need good data if they are to monitor the impact of new initiatives and to maximise the spread of best practice.
- 3.4. The collection of data on teaching quality in schools is the responsibility of the Office for Standards in Education (Ofsted). Ofsted has recently introduced a new system of shorter inspections, lasting two days. Miriam Rosen, Ofsted's Director of Education, explained that these new "Section 5" inspections—unlike the previous ones—"do not include inspection of subjects of the curriculum". Instead, there would be separate subject inspections of "a sample of 30 secondary schools and 30 primary schools" each year. This sample was "not statistically significant" but contained "a range of schools in terms of the socio-economic context, school size, type and geographical location". The subject inspections would "allow strengths and weaknesses and emerging issues to be identified and matters of particular interest to be followed up". The first report into science would be published in 2007–08 (Q 68).
- 3.5. We encountered serious concerns about the adequacy of the new inspection regime for collecting reliable data on the teaching of science. Dr Derek Bell, Chief Executive of the Association for Science Education (ASE), told us that "if you are only going into 20 schools a year, it is not giving you a good evidence base", so a major source of data "is going to be lost" (Q 201). He continued, "if you only have a handful of schools you need to extrapolate that. It just becomes almost meaningless. It is like me quoting an example of my own children at school. You cannot translate that to what is going on all over the country" (Q 203). Dr Bell noted that "we have lots of changes coming in at the moment" and asked, "how are we going to monitor the impact and effects of those changes if we do not have any way of monitoring [them]?" (Q 201).
- 3.6. These concerns were echoed by the Royal Society of Chemistry: "we have serious concerns that the new regime for subject inspections, which is admitted by Ofsted itself to be not statistically significant, will mean that important conclusions from the previous rich bank of data will be unable to be made" (p 79).

- 3.7. **We do not believe that Ofsted’s new regime for the inspection of individual subjects, based on a small and statistically insignificant sample of schools, will provide sufficiently reliable data on science teaching. We recommend that Ofsted revisit the new subject-specific inspection regime with a view to devising a system which draws evidence from a substantially larger number of schools. We further recommend that subject-specific inspections be carried out by specialists in the subject concerned.**

### Specification content

- 3.8. In this inquiry we have deliberately not looked in detail at the science curriculum. However, no matter how high the quality of teaching, it is difficult to engage students effectively unless the specifications too are inspiring. The dangers of uninspiring specifications were plain to see when we spoke to a selection of students at Huntington School, York, all of whom had displayed ability in the sciences. They felt that the sciences did not seem relevant, particularly chemistry; there was too much learning of facts and not enough about the processes and applications of science. There was a consensus that science would be more attractive if it could show itself to be relevant to current issues.
- 3.9. The Qualifications and Curriculum Authority (QCA) recognised this point in its evidence: “the science curriculum must be relevant to the young people who are learning so that they can make sense of it and relate it to their existing knowledge and worldview ... Equipping them effectively with skills and understanding will take them beyond mere accumulation of knowledge, which so easily becomes out-of-date, towards becoming lifelong learners able to adapt to the rapidly changing technological world they will live and work in” (p 192). We strongly endorse this approach.
- 3.10. In line with these priorities, the QCA set out to revise the national curriculum programme of study for science at Key Stage 4 and the GCSE science subject criteria. The Government told us that the new programme of study “maintains the breadth, depth and challenge of the current curriculum, but has a better balance between knowledge and understanding than the existing curriculum” (p 15).<sup>17</sup> The awarding bodies accordingly developed new GCSE science specifications which have been taught since September 2006. Although the majority of students—especially those at state schools—will continue to take double award science, the Government have pledged that “from 2008 ... all pupils achieving at least level 6 at Key Stage 3 [will be entitled] to study three separate science GCSEs”.<sup>18</sup> If this welcome pledge is to be met, our recommendations on teacher recruitment and retention in Chapter 4 must be heeded.
- 3.11. The Nuffield Foundation, which jointly developed and piloted the Twenty First Century Science suite of courses with the University of York, claimed that the courses would “address some of the problems that lead to young people’s disillusionment with school science: an overemphasis on factual recall, a lack of intellectual coherence across existing courses and a lack of relevance to the real world of science and technology that students encounter outside the classroom”. It was hoped that the new courses would thus help to

<sup>17</sup> The details of the programme of study can be seen on pp 193-195.

<sup>18</sup> *Next Steps*, p 3.



“enthuse young people and encourage more of them to study science post-16” (p 184).

- 3.12. The OCR, the awarding body which offers the Twenty First Century Science courses, explained that the introduction of the “How Science Works” section into the QCA Science Criteria “underpins” the changes—“it is intended to make courses relevant to students by showing how scientists work and how the implications and applications of science impact on our lives” (p 187). Ofsted elaborated, noting that “How Science Works” is not confined to carrying out practical science but “involves pupils developing the skills of scientific inquiry, and, through analysis of evidence, arriving at a new understanding of the world around them” (p 39).
- 3.13. The majority of witnesses broadly welcomed the new GCSE courses, particularly the learned societies (see Q 133). This enthusiasm was strongly echoed by the science teachers with whom we spoke at Little Heath School, a science and mathematics specialist school in Reading. There was general agreement at our seminar that the Twenty First Century Science courses would make school science more exciting and relevant to students without “dumbing down” the content. Dr Derek Bell, when asked if the new courses could be more interesting without reducing the amount of real science studied, replied: “The answer is yes, very unequivocally, providing we stick to the rigour and I think the majority of teachers will do that” (Q 214).
- 3.14. The new GCSE specifications were also welcomed by Research Councils UK, which felt that they would be beneficial for teachers as well as students, going “some way to enabling teachers to take ownership of their subject”. The previous specifications had been too detailed, “leading to science teachers feeling too often that they were a de-professionalised cadre of content deliverers”, whereas “the new specifications will free teachers to some extent, enabling them to use their professional expertise to develop engaging activities for their students” (p 198).
- 3.15. However, the ASE regretted that the new GCSEs had been introduced “before all the findings of the [Twenty First Century Science] pilot are known” (p 100), a point confirmed by the Nuffield Foundation (p 184). Moreover, whilst Jules Hault, Head of Physics at Uppingham School, welcomed the Twenty First Century Science courses—which have now been revised—he felt that the other, unpiloted courses “still have all their errors, uncertainties and unfortunate teaching orders” and noted that there was insufficient time to rectify the problems. He concluded: “Some schools are already reporting problems getting to grips with vague syllabus statements that give no indication of what level is required for examination and teachers entering the profession must be finding this very intimidating” (p 152).
- 3.16. **We welcome the new science GCSE courses, although it is essential that teachers should maintain the necessary rigour in their teaching and ensure that the “hard” science is retained. However, it is unfortunate that the Government opted to roll out the new courses before the results of the Twenty First Century Science pilot could be fully evaluated, and before the other, unpiloted courses had been sufficiently scrutinised. We recommend that, in future, the Government should allow more time between piloting new courses and rolling them out across the country. In addition, the Government must keep a very close eye on how the unpiloted courses are bedding down, providing appropriate support where necessary.**

- 3.17. The QCA is also currently reviewing the Key Stage 3 programme of study in order to align it with the new GCSEs and to give schools “greater flexibility to design a curriculum tailored to their own particular needs and circumstances”. Similarly, the specifications for science A-levels are being reviewed “to reduce the assessment burden, reflect subject developments, and provide better progression from the new Key Stage 4 [GCSE] programme of study”. The new courses will be taught from 2008 (p 196).
- 3.18. In principle we welcome these changes. However, Daniel Sandford Smith of the Institute of Physics was concerned by the proposed timetable. He noted that the burden of teaching new A-levels from 2008 will mean that “teachers will need to get the GCSEs right in two years [which] means they are not going to have a chance to revisit what they have done and find more creative ways of teaching the second or third time round”. In other words, science teachers will have barely adjusted to the new GCSEs before having to repeat the whole process with the new A-levels. Mr Sandford Smith felt that the whole programme of change was in danger of being “ineffectively rushed through” (Q 129). A further problem is that there are no plans to pilot any of the new A-level courses.
- 3.19. **We welcome the Qualifications and Curriculum Authority’s (QCA) plans to align the Key Stage 3 programme of study and the science A-levels with the new GCSEs. However, the introduction of the new A-levels in particular must not be rushed. We recommend that the Government review the proposed timetable for introducing the new A-levels, so as to ensure that there is sufficient time for the new GCSEs to bed down and for teachers to adjust before national roll-out. Furthermore, we call on the Government to ensure that some piloting takes place before the new courses are introduced.**
- 3.20. Finally, we draw attention to the new specialised diploma in engineering, due to be introduced in 2008. It is one of 14 proposed diplomas being devised in consultation with the Sector Skills Councils with the aim of providing students with “real world” knowledge and skills—through work experience—whilst they are learning. The diplomas will have different levels of difficulty and are aimed at students of all abilities. The highest level of diploma will be accepted by colleges and universities. Whilst we look forward to seeing how this initiative progresses, we are seriously concerned that the diplomas may produce a binary divide within the education system, pigeonholing some lower ability students into a particular career path at too young an age.

### **Enriching science teaching**

- 3.21. To enhance the learning experience, science and mathematics teachers should aim to make full use of the resources available to enrich their teaching and inspire their students. In the words of the Science Learning Centres: “students enjoy variety, and for effective learning, a range of teaching methods is needed, including group discussion, computer assisted learning, and science outside the classroom” (p 176). In this section we focus on the role that can be played by IT facilities, museums and ambassadors from industry or academia.
- 3.22. The use of IT facilities can greatly enhance students’ enjoyment of science classes; as Ian Richardson of Ofsted told us, “there are some very dramatic examples where students’ engagement and enjoyment has lifted because of judicious and skilful use of ICT interactive whiteboards and a range of other

- ICT applications and devices” (Q 91). However, the National Advisers and Inspectors Group for Science (NAIGS) warned us that “in NAIGS surveys, most schools have reported insufficient access to ICT equipment, particularly within the science departments (as opposed to school ICT suites)”. Nonetheless, they noted, “the use of laptops, data projectors and interactive whiteboards in science is increasing” (p 162).
- 3.23. During our visit to Little Heath School we saw the enormous impact of ICT equipment, allowing the teacher to guide students through biology research on the internet. This interactive approach to use of the internet clearly enhances student engagement, particularly when exciting websites are used. For example, the Planet Science website (provided by the National Endowment for Science, Technology and the Arts, NESTA) is, in the words of NESTA, “packed full of resources to inform, inspire and stimulate science learning” (p 167). Similarly, the Bradford Robotic Telescope allows students to access images of space whilst learning about the basics of astronomy (see pp 133–135).
- 3.24. Museums can also be an invaluable resource, inspiring students and revealing links between science and the real world. We were delighted to receive submissions from organisations as diverse as the Royal Armouries, the Natural History Museum, the National Maritime Museum, the Science Museum and the Stoke-on-Trent Museums Service. The Real World Science Project, a Government-funded partnership, uses museums’ collections, galleries, curators, scientists and educators to deliver a learning programme for secondary science students. According to the partnership, 40 per cent of visiting students “felt that their feelings towards science had changed positively as a result of their museum visit”, and 13 per cent responded that they “had been inspired to continue studying science” (p 225). Such initiatives are welcome, but teachers must also play a full role in ensuring visits are followed up in the classroom and embedded in learning.
- 3.25. The network of over 80 interactive, hands-on science and discovery centres across the United Kingdom also makes a great contribution to engaging young people in science. For example, the INTECH Science Centre near Winchester houses over 100 exhibits “which communicate the fundamental principles of science and technology and their applications in industry and the home”, and offers workshops covering many areas of relevance to the curriculum.<sup>19</sup> We strongly endorse the use of such facilities by schools and families alike.
- 3.26. Amongst the most valuable external resources for science teaching are industry and academia, whose representatives can enhance science lessons and act as role models for students still considering what career path to follow. Crucially, as the Science Learning Centres noted, these links can “keep teachers in touch with the front line of scientific research and the applications of science in industry, helping them find ways to bring interesting and relevant contexts into their teaching” (p 178). There are a number of valuable schemes in this area such as Research Councils UK’s Researchers in Residence scheme and the Royal Society’s Partnership Grants scheme, which help bring scientists and engineers into the classroom to help with teaching.

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<sup>19</sup> See <http://www.intech-uk.com>.



- 3.27. Another key initiative is the Science and Engineering Ambassadors Programme, funded by the Government, which currently sends 12,000 volunteers involved in STEM to schools across the United Kingdom. SETNET commented that these volunteers can “act as role models, provide exciting and novel demonstration or project ideas to teachers, and offer assistance with and access to valuable curriculum enrichment activities” (p 216). Feedback on the Ambassadors programme has been positive, and we welcome the Government’s aim to expand the scheme so that “by 2007–08 the total number of ambassadors will be 18,000, an increase of 50 per cent” (p 14).
- 3.28. However, there was some concern from the Biosciences Federation that academics and university students wanting to lend their expertise to schools are “at best unrewarded and at worst actively discouraged” because “it is not recognised as a ‘worthwhile’ activity within the RAE [Research Assessment Exercise] framework” (Q 108, p 66). Indeed, whilst some external activities are recognised by the RAE as “indicators of esteem”, outreach work in schools is not generally acknowledged at all. A connected problem is that the universities themselves often do not look favourably upon such activities.
- 3.29. The severity of this problem was highlighted by a recent Royal Society survey of almost 1,500 research scientists: “according to the scientists ... the pressure to publish research, attract funding to their departments and build careers on ‘hard research’ means public engagement work, such as ... outreach activities with schools, is not a priority”. Moreover, “45 per cent of respondents said that they would like to spend more time engaging with the non-specialist public about science”.<sup>20</sup> The challenge is to build an understanding amongst scientists, engineers, academic institutions and funding councils that public service such as outreach work in schools is of great value in itself, and should also be acknowledged and included in RAE submissions.
- 3.30. **Whilst we welcome the existing schemes that bring scientists and engineers into the classroom, particularly the Science and Engineering Ambassadors Programme, we are concerned that academics and university students receive little recognition for helping to inspire the next generation of scientists in schools. We recommend that the Government work with the funding councils to ensure that outreach work in schools is properly valued as part of the RAE, and to encourage higher education institutions to provide details of any such work in their submissions.**
- 3.31. It is also highly beneficial for students to spend time in the workplace, laboratory or field. It not only gives them experience of the attractions of a STEM career, but helps them demonstrate their commitment to both universities and potential employers. The Royal Academy of Engineering’s Best Programme undertakes very valuable work in this area, for example through the Engineering Education Scheme and the Headstart Programme. Similarly, the Nuffield Science Bursary Scheme helps students to work alongside practising scientists on a project, and GlaxoSmithKline provides Year 11 and Year 12 students with the opportunity to work with scientists in the company’s laboratories. Such opportunities should be promoted energetically by teachers.

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<sup>20</sup> See <http://www.royalsoc.ac.uk/news.asp?id=4861>.

- 3.32. However, the range of enrichment activities outlined above creates its own difficulty: how to promote them to teachers and students in a co-ordinated and comprehensible manner. There is some evidence that the vast array of different schemes offered by a range of different organisations, and the large selection of websites, museums and other resources, are overwhelming for potential users. As the Society for General Microbiology opined, “the multiplicity of schemes is confusing and some streamlining would be helpful” (p 218). This issue was recognised in the Government’s STEM mapping review, published in August 2004, which recommended that “coherence and co-ordination are brought to these programmes/initiatives”.<sup>21</sup> The Government have subsequently developed an ongoing cross-cutting programme in STEM.
- 3.33. Substantial action is already underway. In response to a recommendation in Sir Gareth Roberts’ review, *SET for success*, a Regional STEM Support Centre is being developed in each of the nine English regions in order “to establish a single recognised channel through which schools can access schemes aimed at enthusing and educating pupils in Science, Technology, Engineering and Mathematics”.<sup>22</sup> This initiative is being undertaken by SETNET (which will provide the director of each STEM Support Centre) with partners including the Regional Development Agencies and the Science Learning Centres (each of which will provide an ex-officio member to the local STEM Support Centre).
- 3.34. Whilst the functions of the new STEM Support Centres appear to overlap significantly with SETNET’s existing regional SETPOINTS, this initiative is welcome. The key challenge will be to ensure that all schools and teachers are made aware of the STEM Support Centres and that they provide sufficiently user-friendly and up-to-date information to encourage ongoing use, particularly by those schools which have traditionally failed to become involved in enrichment activities. In addition, whilst the Science Learning Centres told us that the STEM support Centres would employ “a common STEM support portal” (p 177), it is important that each region has its own section, detailing national schemes as well as those only available locally.
- 3.35. **We welcome the formation of the Regional STEM Support Centres as a means to provide a single, simple source of information on STEM enrichment opportunities. However, the web portal must be comprehensive and accessible. We therefore recommend that there be separate sections for each region, so that the content is tailored to the audience, and teachers and students are thus able to obtain information with the minimum time and effort.**

### The impact of testing

- 3.36. Testing plays an increasingly large role in school life, with students facing compulsory tests at the ages of seven, 11 and 14. As the Science Learning Centres stated, “testing dominates the teaching of science at the upper end of primary schools and in secondary schools at all levels” (p 175). It is therefore necessary to consider the nature of this testing and the impact that it has upon the teaching of science and mathematics.

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<sup>21</sup> DfES, *Science, Technology, Engineering and Maths (STEM) Mapping Review*, August 2004, p 2.

<sup>22</sup> Written evidence (not published).

- 3.37. Although the teachers at Little Heath School felt that testing helped to focus the minds of both students and teachers, there was widespread agreement amongst witnesses that the current nature and level of testing was having a deleterious effect upon science and mathematics teaching. In particular, there was concern that the testing regime was resulting in a culture of “teaching to the test”, whereby the nature of the tests and the pressure for their students to score well pushes teachers into narrow and uninspiring methods of teaching.
- 3.38. The Mathematical Association was particularly concerned about this problem, commenting, “many teachers feel seriously constrained by a system that is increasingly ... dominated by the assessment and accountability system, which encourages a narrow ‘teaching to the test’ which focuses exclusively on rehearsing skills and solving standard problems”. This form of teaching “compromises the enthusiasm of both teachers and students, fails to develop students’ ability to think independently and detracts from their enjoyment of mathematics” (p 158). The Association concluded that “a radical shift away from the current dominance of tests, examinations, targets and league tables is essential if standards in mathematics are to be improved” (p 157).
- 3.39. The ASE agreed that “teaching to the test leads to a narrowing of not only teaching approaches and activities but also to the quality of knowledge and understanding gained by pupils and their engagement with the subject” (p 94). One symptom of such teaching, in the opinion of the Science Learning Centres, was that teachers had less time to provide students with enjoyable and inspiring activities such as practical work, discussion of ideas and visits outside the classroom (p 176).
- 3.40. The impact of this was highlighted by the National Advisers and Inspectors Group for Science (NAIGS), which commented that “research has identified a deterioration in attitudes to science during KS3, and we believe this is ... partly a result of preparation for tests” (p 161). This suggests that uninspiring “teaching to the test” can give students a bad impression of science and mathematics in the years leading up to GCSE and A-level—the very time when it is so important to convince students that the subjects are relevant and exciting.
- 3.41. Thus the pressure for teachers and students to perform well in tests can in itself contribute to uninspiring teaching. In addition, the Science Learning Centres criticised the nature of the tests themselves, because they “assess a narrow range of skills” and are dominated by factual recall, which in turn adversely impacts upon the way in which teachers prepare their students (p 175). A similar point was made in a recent report by the Teaching and Learning Research Programme, which reported that the tests failed “to assess the full range of skills and competencies that should be the goals of science education”.<sup>23</sup> If the tests were broader and less dominated by factual recall, allowing more flexibility in teaching and requiring a wider range of skills, it could be that “teaching to the test” would not necessarily be the problem that it is at the moment.
- 3.42. **We are seriously concerned about the impact that the national testing regime is having upon the teaching of science and mathematics. We**

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<sup>23</sup> Teaching and Learning Research Programme, *Science Education in Schools: Issues, evidence and proposals*, March 2006, p 10.

**call on the Government to ascertain as a matter of urgency how the tests can be altered so as to assess a much broader range of skills, thus allowing the teacher greater flexibility in inspiring students in the classroom.**

### **The role of the practical**

- 3.43. Practical work—both in the classroom and outdoors—is an absolutely essential component of effective science teaching. As the Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS) noted, “appropriate practical work enhances pupils’ experience, understanding, skills and enjoyment of science” (p 109). Moreover, NESTA commented that practical work “allows science education to become something that learners participate in, rather than something they are subject to” (p 165) and, in the words of the QCA, supports “aspirations towards further study and science-related work” (p 195).

### *The current situation*

- 3.44. Some witnesses felt that the volume and variety of practical work in schools had lessened over time. A key cause of this was the focus on “teaching to the test”, which squeezed out some types of practical work. As CLEAPSS pointed out, “teachers are being required to achieve better examination results and one response to this has been to focus more on ‘book learning’ which is more easily managed and assessed” than practical work. Moreover, teachers had “insufficient opportunity ... to learn about, and practise, activities before lessons” (p 110). Similarly, the Science Learning Centres noted, “many teachers complain that, with pressure to get through the syllabus, they cannot find room for much practical work” (p 176). A NESTA survey had reinforced these impressions, with “a lack of time” being cited by 64 per cent of teachers—more than any other issue—as a barrier to practical work (p 165).
- 3.45. Even when teachers can find time for practical work, there is concern about the lack of variety, particularly at GCSE level. CLEAPSS suggested that “a desire to ensure that ... investigations can be both rigorously assessed and enable candidates to do their best has meant that schools choose only those known to work well and conform to certain specifications”. This had led to “perhaps as few as 10 different investigations forming the bulk of science GCSE coursework throughout the country” (p 112).
- 3.46. This point was echoed by the Science Learning Centres: “the national tests at ages 14 and 16 require teachers to assess practical skills, but the highly specific criteria against which this assessment takes place tends to lead to a formulaic approach more akin to jumping through hoops than carrying out true scientific enquiry” (pp 176–177). Whilst it is to be hoped that the new GCSEs will improve the situation, these issues again emphasise the need to modify the assessment regime, allowing space for genuinely open-ended practical work.
- 3.47. The problems facing practical science are particularly serious in the case of fieldwork. The Field Studies Council warned that “fieldwork provision in science and biology is declining in British secondary schools. A minority of 11–16 students will now venture outside the classroom and even in A-level biology nearly half the students will do no fieldwork, or will only have a half-day experience near to their schools”. This decline was spreading to



universities and “appears to be leading to a shortfall in people with the practical skills needed to support biodiversity and teaching related careers and activities” (p 150). The British Ecological Society concurred, warning that “urgent changes are needed to policies and the level of resources available to enable students to have meaningful fieldwork experiences” (p 137).

### *Teacher attitudes*

- 3.48. Another threat to practical science comes from the attitude of teachers themselves. As CLEAPSS commented, “a lack of experience, expertise and training are some of the factors which have led to teachers making less use than before of practical work, both demonstrations and class practicals” (p 109). The Science Learning Centres agreed: “many teachers ... lack the experience and confidence to carry out the kind of practical work that can stimulate and inspire” (p 177).
- 3.49. The provision of information on practical work for teachers is improving. CLEAPSS already provides advice to members through a telephone helpline, whilst the Nuffield Foundation together with the Institute of Physics has developed a “Practical Physics” website with details of over 400 experiments. Moreover, the Foundation and the Royal Society of Chemistry are intending to launch a similar site for chemistry later in the year. However, whilst these sources of information are welcome, the most effective help for teachers comes in the form of initial teacher training and continuing professional development (CPD). We discuss CPD in depth in Chapter 6, but at this point we note with concern that science teachers’ uptake of CLEAPSS practical science courses has fallen very significantly over the last 10 years—although the uptake of such courses by science technicians has risen (p 109).
- 3.50. Even if teachers do feel sufficiently confident to undertake exciting practicals, some appear to be held back by health and safety concerns. Indeed, such is the concern of the scientific community on this matter that the Royal Society of Chemistry commissioned CLEAPSS to carry out a major study entitled *Surely that’s banned*, which surveyed the attitudes of schools and local education authorities towards practical work. The report concluded that “there are significant misunderstandings on the part of teachers and technicians about the chemicals and scientific activities which are banned in secondary schools and some teaching is inhibited by unjustified concerns about health and safety”.<sup>24</sup>
- 3.51. This problem was emphasised by NESTA, whose survey showed that 87 per cent of science teachers had “at least once prevented their students from undertaking practical work because they believed current health and safety regulations prohibit them from doing so” (p 163). Tom Dawson, a teacher of physics A-level, noted that “conducting class experiments has become a huge burden. Health and safety is burdensome where confidence among teachers is lacking; indeed, H&S has become an industry in its own right, stifling excitement” (p 145). Dr Colin Osborne of the Royal Society of Chemistry elaborated further: “people are very

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<sup>24</sup> CLEAPSS, *Surely that’s banned? A Report for the Royal Society of Chemistry on Chemicals & Procedures Thought to be Banned from Use in Schools*, October 2005, p ii.

worried about health and safety issues and they become ill-informed because there is ... a perception that you cannot do things and chinese whispers takes place so that people think certain experiments are banned” (Q 139). Phil Bunyan of CLEAPSS echoed this, referring to a “very real fear of litigation” and pointing out that “the power of myth and rumour ... is very hard to contradict” (Q 231).

- 3.52. In reality, CLEAPSS told us, “health and safety concerns are a real constraint in only a tiny number of practical activities, and, even for these, CLEAPSS offers advice on suitable alternative chemicals, equipment or procedures” (p 111). The key challenge is to convey this message to teachers, ensuring that they have ready access to clear and comprehensive information on any practical work which they may wish to undertake. The Society for General Microbiology stated that “clearer guidance should be made available on safety issues as it is SGM’s experience that teachers ... do not know where to find authoritative advice” (p 218). Dr Osborne agreed that there was a need for “more publicity for teachers to tell them where to find information”, whilst Dr Sue Assinder of the Bioscience Federation called for “exemplar practicals that have been risk assessed that are not things followed step-by-step but are open-ended so that teachers can inspire the students” (Q 143).
- 3.53. A related issue is teacher concern about undertaking practical work in classes with an excessive number of students or with poorly-behaved individuals. The National Union of Teachers called for consideration to be given to “a nationally agreed and enforced upper class size limit for practical science lessons” (p 83). Whilst this is an admirable aim, it is difficult to see how a class size limit could be imposed on practical science lessons without imposing the same limit on all science lessons, because it would not be possible to exclude some of the class when practical work is being undertaken. Clearly, lower class sizes are desirable for all subjects, including science and mathematics, but there are enormous cost implications. In the absence of an increase in resources overall, it must remain the responsibility of the head teacher to muster his or her resources in the most effective way for the school as a whole. For example, higher level teaching assistants can potentially play an important role in helping teachers to maintain discipline in the classroom.

#### *Condition of laboratories*

- 3.54. An issue repeatedly blamed by witnesses for impairing the effective teaching of practical science was the condition of school laboratories. In 2004, the Royal Society of Chemistry commissioned CLEAPSS to research this issue. The results of the survey are set out in Table 2:

TABLE 2

Results of a survey of lab condition (taken from *Laboratories, Resources and Budgets*)

Description of lab condition	Number in sample	% in sample	Number estimated for all maintained schools in England
Excellent	280	5%	1,315
Good	1,641	30%	7,770
Basic (uninspiring)	2,262	41%	10,695
Unsafe/unsatisfactory	1,386	25%	6,560
<b>Total</b>	<b>5,569</b>	<b>100%</b>	<b>26,340</b>

Source: CLEAPSS

- 3.55. As the Royal Society of Chemistry commented, these results make “unsettling reading”, with an astonishingly high total of 66 per cent of school laboratories rated as basic (uninspiring) or unsafe/unsatisfactory. There was also an insufficient number of laboratories, with teachers reporting that “on average, one additional laboratory per school is required to allow all science lessons to be taught in a laboratory. This equates to an under-provision of at least 3,518 laboratories” (pp 48–49). Finally, only 36 per cent of preparation areas were described as good or excellent, with 21 per cent described as poor (p 112). The impressions presented by this study were backed up by anecdotal evidence. For example, Francisco DaCosta, Head of Physics at Blake Valley, Staffordshire, was disillusioned by “the conditions of the ancient laboratories and the even more dated scientific apparatus” (p 143).
- 3.56. Ofsted agreed that “in too many schools ... accommodation remains less than satisfactory” and noted that such accommodation “hinders teaching and learning”. Indeed, “inspection data show a clear positive correlation between the quality of accommodation and the quality of teaching”. In consequence, there was “a clear need for improved standards of accommodation” (p 40).
- 3.57. The funding implications of improving laboratory provision are significant: the Royal Society of Chemistry found that “if all issues are addressed at once, the total finance needed is estimated to be in the region of a staggering £1.38 billion. This represents the total cost to upgrade to a good standard only” (p 49). The Schools Minister, Jim Knight MP, when asked about this issue, pointed to the Building Schools for the Future (BSF) programme which aims “to replace or refurbish all secondary schools by 2020”. In total, he added, capital spend on schools had increased ten-fold over ten years (QQ 57, 58).
- 3.58. Although the funding increases are impressive, the National Union of Teachers insisted that “funding needs to be specifically earmarked ... to improve the quality of science laboratories” (p 82). Otherwise, there is a risk that head teachers will shift funding away from science and towards more popular subjects. This can create a “vicious circle” whereby money is moved

away from science laboratories, which then deteriorate and act as a deterrent to prospective science students, thus resulting in even fewer students taking science and a greater reluctance to spend money on science laboratories.

- 3.59. Moreover, there was consternation from both the ASE and the Campaign for Science and Engineering in the United Kingdom (CaSE) that the extra £200 million—or £75,000 per school—of additional funding for school science laboratories pledged by the Government (on top of the BSF programme) in the run-up to the 2005 General Election had not been delivered (pp 101, 141). The Government's failure to meet this pledge, which had been reaffirmed by the Prime Minister, was confirmed in a letter to John Dunford, General Secretary of the Association of School and College Leaders (ASCL).<sup>25</sup>
- 3.60. Money in itself is not sufficient to improve the quality of school laboratories: the money must be spent wisely and appropriately. During our visit to Little Heath School we saw how a number of laboratories had been quickly and effectively upgraded for £30,000, which had in turn increased the teachers' ability to offer innovative and exciting practical work. However, CLEAPSS was concerned that in general "the quality and effectiveness of recently rebuilt or refurbished school science laboratories is too often below an acceptable standard" (p 124).
- 3.61. The data in a draft report being prepared by CLEAPSS for the Royal Society of Chemistry, with support from the Royal Society, reveal that 28 per cent of science departments "thought the quality of their new or newly refurbished labs was unsatisfactory or poor" and that, astonishingly, 33 per cent of science staff "had little or no involvement with the design or refurbishment". CLEAPSS felt, therefore, that "more care is needed by all concerned when planning, commissioning and designing new or refurbished science laboratories if they are to be fit for purpose and sufficiently durable" (p 124).
- 3.62. Addressing this issue, Schools Minister Jim Knight referred us to the "School Labs of the Future" programme, which aimed to bring together designers, experts in science teaching and schools to develop exemplar designs for laboratories that could be used as part of the BSF programme to create "inspirational learning environments" (Q 58).
- 3.63. In response, however, Phil Bunyan of CLEAPSS said, "I know the Government has a project to build exemplarily but we have seen some of the specifications of science labs and frankly they are woefully inadequate" (Q 236). He decried the "inconsistency and evident lack of care" in the relevant documents and warned that they could result in laboratories which are "a constraint on effective science teaching" (p 125). Indeed, CLEAPSS had not been consulted on the specifications and had only seen them because "we know somebody who had them ... it looked like an administrative oversight" (Q 237). Moreover, Dr Derek Bell of the ASE told us that his organisation had attempted, without success, to become involved in the BSF programme itself but "we are not getting anywhere with that at all" (Q 238).
- 3.64. **Practical science is at risk in our schools. We urge the Government to take the following action:**

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<sup>25</sup> See: <http://www.epolitic.com/EN/Forums/Association+of+School+and+College+Leaders/PressReleases/200603/5951228e-3c31-42a4-afa7-472bfd4fb513.htm>.



- **We call on the Government to review the place of practical science within the national tests as a matter of urgency so as to secure the future of genuinely open-ended, investigative science both inside and outside the classroom. Similarly, the new A-levels should place greater emphasis on practical work, including that outside the classroom or laboratory.**
- **We recommend that the Government assess the feasibility of a unified and comprehensive central website dedicated to practical work in all the sciences. Such a website, which could be closely linked to the Science Learning Centres' web portal, should offer health and safety advice and exemplar practicals that can stimulate students.**
- **Significant funding is required to remedy the unsatisfactory state of many school science laboratories. We therefore deplore the Government's failure to deliver the £200 million promised for school science laboratories during the 2005 General Election campaign. We welcome the Building Schools for the Future programme, but are concerned that an insufficient amount of the funding will be spent on improving science laboratories. It is not the role of central Government to determine in detail how schools spend their budgets, but we recommend that the Government, together with local education authorities and Ofsted, initiate a campaign to persuade schools of the huge importance of high quality laboratories.**
- **The low quality of so many new or refurbished science laboratories is both regrettable and avoidable. We are mystified that the Government, in developing exemplar designs as part of the "School Labs of the Future" programme, have failed to consult acknowledged authorities such as the Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS) and the Association for Science Education (ASE). We recommend that the Government rectify this omission immediately.**

### **Role of technicians**

- 3.65. Science technicians are of central importance in the provision of effective and exciting practical work in science classes, helping teachers by preparing, maintaining and managing the resources needed for practical activities. Furthermore, as the Science Learning Centres commented, "good technicians can transform the morale of a department by ensuring its smooth running and providing support and guidance for less experienced teachers" (p 178). At the same time, a lack of technicians can have a seriously harmful effect: Ian Richardson of Ofsted told us, "I do come across teachers who, when technician support is lighter, withdraw from doing practical work and therefore revert to a rather more didactic approach to ... teaching" (Q 88).
- 3.66. There was some concern amongst witnesses that the supply of science technicians in schools was often inadequate. The ASE claimed that "the level of technician support for science in schools is not adequate by any of the commonly used measures" and warned that "without adequate numbers of science technicians the learning experiences of students will be impaired ...

and safety in school laboratories will be compromised”. It was suggested that “up to 4,000 additional science technicians” should be recruited (p 107).

- 3.67. Even in cases where there are enough technicians, many of them tend to be part-time and do not work during the school holidays. This, in the words of CLEAPSS, “seriously restricts the capacity to undertake annual or termly maintenance and servicing of laboratories and stores” (p 115).
- 3.68. This highlights the need to professionalise the role of the science technician and to create a more attractive career path. As one science teacher told us, technicians are often seen by senior management as “glorified washer-uppers” (p 147). Not surprisingly, many technicians view their job as a “stop-gap” and do not regard it as a viable long-term career. For example, of the four technicians we spoke to at Huntington School, York, two were graduates but both were expecting to leave in the foreseeable future because the pay was very low and there was little prospect of career advancement.
- 3.69. The ASE, in partnership with the Royal Society and CLEAPSS, has proposed a career structure for technicians consisting of four tiers: Assistant Technician, Technician, Senior Technician and Team Leader Technician.<sup>26</sup> This structure is underpinned by a new National Vocational Qualification, Laboratory and Associated Technical Activities (LATA). In taking the NVQ, technicians will be supported through a “virtual” centre, the Technicians’ National Assessment Centre, which will allow them “to engage with the qualification without having to regularly attend sessions away from the workplace”.<sup>27</sup> The scheme is being piloted and is expected to be made available nationally in 2007.
- 3.70. However, Dr Derek Bell, Chief Executive of the ASE, expressed disappointment that “when the Government brought in their workforce agreement [they] did not have a category which was specifically for technicians ... because they were seen as being linked to the teaching assistants” (Q 245). This impression was reinforced by the Schools Minister, Jim Knight MP, who, when speaking about career progression for technicians, focused on “progression through to higher level teaching assistants” which would “give them great satisfaction and allow them to use their enthusiasm for science more effectively” (Q 64). Whilst it is important that technicians should have the opportunity to become higher level teaching assistants, the two careers are distinct. The Minister’s words risk giving the impression that the technician’s work is not as worthwhile as that of a teaching assistant. Technicians must be assured that they can have a fulfilling career that enables them to progress whilst remaining technicians.
- 3.71. It is also important that technicians should have the opportunity to undertake continuing professional development (CPD) and thereby maximise their chances of progressing in their career. CLEAPSS reported that an increasing number of technicians were taking their CPD courses and the Science Learning Centres noted that they too had experienced “strong demand” from technicians since opening, which is welcome (p 178). However, it remains necessary for the Government and other bodies such as the ASE to convey consistently to schools the value of sending their technicians on such courses.

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<sup>26</sup> See [http://www.ase.org.uk/htm/homepage/career\\_structure/careerstructure.pdf#search=%22career%20structure%20technicians%20ase%22](http://www.ase.org.uk/htm/homepage/career_structure/careerstructure.pdf#search=%22career%20structure%20technicians%20ase%22).

<sup>27</sup> See <http://www.techcen.org.uk>.

**3.72. A motivated and well-trained supply of technicians is an essential component of effective science teaching. We therefore wholeheartedly endorse the ASE's proposed career structure for technicians, the new NVQ and the virtual assessment centre. We recommend these proposals to the Government, and in addition invite them to consider whether the career structure could be linked to advisory salary scales, in an attempt to increase the almost universally low level of pay for technicians.**

## CHAPTER 4: TEACHER RECRUITMENT AND RETENTION

- 4.1. Ensuring that there is a sufficient supply of qualified and well-trained teachers is crucially important in the teaching of science and mathematics, as with any other subject. In order to monitor the situation, both in terms of vacancy levels and in terms of the number of teachers teaching outside their own subject area, accurate and comprehensive data are essential.
- 4.2. However, some witnesses expressed concern that such data were not available. The National Union of Teachers (NUT), for example, told us that the data have not been “sufficiently robust to draw significant conclusions on staffing for science” (p 81). Similarly, the ASE, whilst praising the recent study undertaken by the National Foundation for Educational Research (NFER),<sup>28</sup> noted that it was “unaware of any plans to systematically monitor the situation over the coming years” (p 95). The Royal Society also wanted to know how the Government were intending to “keep track of [their] own progress by the regular collection of detailed data on the qualifications and deployment of teachers” (p 61).
- 4.3. When we asked Schools Minister Jim Knight MP about this issue, he recognised that “we could and should do better in order to fulfil the aspirations we have got to improve the recruitment and retention of teachers in science”. He went on to assure us that “from 2008/9 we will require every school through IT to be able to submit returns to us on an annual basis right down to individual teacher level so that we can monitor ... what the movement is and what the trends are” (Q 21). This is a welcome initiative, and we trust that the Government will do everything necessary to ensure that the necessary IT systems are in place in order that it can start on schedule.

### Teacher shortages

- 4.4. The scale of teacher vacancies in science and mathematics is a major concern. Ofsted, quoting from Her Majesty’s Chief Inspector’s 2004/5 report, said that “since 1998 the teacher vacancy rate [in science] has nearly quadrupled and in January 2005 the number of unfilled posts was 250, the highest for any subject” (p 39). The NUT also noted that “targets for recruitment to science teaching have only been met in three years (1991–1993) in the last 25 years” (p 81). However, it appears that the situation has started to improve in the last few years. The Government told us that the number of people training to become teachers had increased “by 18 per cent in science and 41 per cent in mathematics from 2001/02 to the present”, and that the science and mathematics teacher vacancy rate had been reduced “to 0.9 per cent from 1.6 per cent in 2001 and 1.0 per cent from 2 per cent respectively” (pp 1–2).
- 4.5. One of the most crucial problems regarding recruitment of science teachers is the availability of people appropriately qualified to teach the subject, especially in the case of physics, chemistry and mathematics. The NFER report mentioned above provides the most up-to-date analysis of who exactly is teaching the sciences and mathematics in schools. It found that, of all secondary science teachers:

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<sup>28</sup> National Foundation for Educational Research, *Mathematics and science in secondary schools: the deployment of teachers and support staff to deliver the curriculum*, January 2006. Commissioned by the DfES.

- 44 per cent were biology specialists (i.e. either held a degree in the subject or specialised in the subject during initial teacher training);
- 25 per cent were chemistry specialists; and
- 19 per cent were physics specialists.

Moreover, only 76 per cent of mathematics teachers were specialists in the subject. Accordingly, the report noted, “many schools are using non-specialists or teachers of other subjects to make up for the shortfall of scarce specialists”. Worryingly, this practice tended to be most widespread in the lowest attaining schools, those serving areas of socio-economic deprivation and those with an 11–16 age range.<sup>29</sup>

- 4.6. The Royal Society of Chemistry, responding to these findings, commented that “there are some schools without a single appropriately qualified chemistry or physics teacher and a substantial number in which the majority of Key Stage 3 and Key Stage 4 science lessons are taught by biologists or those without a mainstream science qualification” (p 46). The Mathematical Association also expressed concern about the “hidden shortage” of mathematics teachers caused by the employment of many teachers “with weak subject knowledge and inadequate training in teaching the subject” (p 158).
- 4.7. Physics appears to face the most serious problem of all. A report by the Centre for Education and Employment Research at the University of Buckingham found that “in the schools and colleges of England and Wales, 37.7 per cent of the teachers of physics/physical processes to 14–18 year-olds had physics as their main subject of qualification”.<sup>30</sup> The Confederation of British Industry (CBI) claimed that “at GCSE level 30 per cent of physics teachers do not have an A-level in the subject” (p 143), and the NFER report found that one quarter of 11–16 schools have no physics specialists at all.<sup>31</sup>
- 4.8. The precarious situation with physics specialists does not look set to improve. The report by the Centre for Education and Employment Research reported that “the stock of physics teachers qualified in physics is diminishing”, explaining that whereas 39.0 per cent of those leaving the profession in 2004 had physics as their main subject, this was true of only 32.8 per cent of newly appointed teachers. Indeed, “current levels of physics teacher training output are barely sufficient to maintain the status quo”.<sup>32</sup> Research Councils UK also pointed out that “the age profile for physics teachers is significantly older than that for teachers of the other sciences and maths” (p 198) and the Institute of Physics expected “around a third of current physics specialists to retire in the next ten years”. In summary, the Institute warned, “the situation is likely to become much worse” (p 51).
- 4.9. What impact does non-specialist teaching have upon students? Whilst some teachers can teach effectively outside their own specialism, particularly if they have had the requisite training, witnesses were clear about the potential

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<sup>29</sup> *ibid*, pp vi, 41 and 106.

<sup>30</sup> Centre for Education and Employment Research, University of Buckingham, *Physics in Schools and Colleges: Teacher Deployment and Student Outcomes*, November 2005, p i. Commissioned by the Gatsby Charitable Foundation.

<sup>31</sup> *Mathematics and science in secondary schools*, p 137.

<sup>32</sup> *Physics in Schools and Colleges*, p iii.



downsides of being taught by a non-specialist. Ian Richardson of Ofsted was unequivocal: “detailed data ... shows a clear correlation between the match of teachers to the specific curriculum components within the science field and the success stories, the quality of teaching and the success of pupils as measured by their achievement” (Q 75). This was backed up by the Centre for Education and Employment Research’s report, which found that “teachers’ expertise in physics as measured by qualification is the second most powerful predictor of pupil achievement in ... physics after pupil ability”.<sup>33</sup>

- 4.10. Alongside the effect on student achievement, there can be an adverse impact on students’ perception of the subject in question. The Science Learning Centres stated that “incomplete understanding and lack of confidence in a subject limits the ability of a teacher to provide deep and inspiring subject knowledge” (p 173). Similarly, the Particle Physics and Astronomy Research Council (PPARC) commented that non-specialists “are unlikely to have the subject knowledge or confidence to enable them to bring exciting contemporary physics ... into the classroom” (p 191).
- 4.11. Inevitably, this can have a knock-on effect on students’ subject choices and indeed career choices. As the Biosciences Federation warned, poor quality teaching by a non-specialist “deters students from further study and so they are less likely to take up a science subject at A-level” (p 65). Moreover, the Royal Astronomical Society noted that “whereas teachers teaching inside their specialist area can often inspire young people into considering a career in science, when teachers are non-expert (or worse not interested) in the science subject they have to teach, it can completely turn-off the young person” (p 203).
- 4.12. To counter the shortage of teachers specialising in physics, chemistry and mathematics, the Government have introduced some highly ambitious targets as part of their *Next Steps* programme. The aim is to “step up recruitment, retraining and retention of physics, chemistry and mathematics specialist teachers so that by 2014 25 per cent of science teachers have a physics specialism (compared to 19 per cent currently), 31 per cent of science teachers have a chemistry specialism (compared to 25 per cent currently) and the increase in the number of mathematics teachers enables 95 per cent of mathematics lessons in schools to be delivered by a mathematics specialist (compared with an estimated 88 per cent currently)” (p 2).
- 4.13. Whilst these targets display admirable ambition on the part of the Government, there is some doubt as to how they will be achieved. The Royal Society of Chemistry called the targets “laudable, but short on detail” (p 47) whilst the Institution of Engineering and Technology claimed that “there has been no announcement on delivery or how to achieve these important changes” (p 154). Similarly, the Institute of Physics warned that “there does not seem to be a well-defined strategy for achieving this goal” (p 51).
- 4.14. The ASE was doubtful about how realistic the targets were in any case: “with a decline in trainee teachers of physics and chemistry in recent years, an ageing science teacher population, especially with physics and chemistry specialisms, rising salaries for new science graduates and 40 per cent of

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<sup>33</sup> *ibid*, p i.

science teachers leaving in [the] first five years, it is unlikely that the Government targets ... will be met” (p 96). Similarly, Research Councils UK called the targets “extremely challenging” (p 198). Nonetheless, we believe that every effort must be made to get as close to the targets as possible.

### **Achieving the Government’s targets**

- 4.15. There are essentially three ways in which progress can be made towards meeting the Government targets: recruiting more physics, chemistry and mathematics specialists into teaching; training more existing or prospective teachers to teach effectively outside their specialism; and improving the retention rate of teachers, particularly specialists. Whilst the first is clearly the more desirable long-term approach, Research Councils UK warned that “it will not be sufficient to rely on the supply of new graduates entering PGCE courses” (p 198). Similarly, the Institute of Physics said that “with an average of only around 2,400 UK physics graduates each year, this shortage of teachers cannot be rectified from that source in the short to medium term” (p 52).
- 4.16. Thus in the short to medium term it will be necessary to rely heavily on training existing and prospective teachers to teach outside their own specialism. As the National Advisers and Inspectors Group for Science (NAIGS) opined, “in the short term it is much better to equip the current workforce with the skills to teach outside their own area, rather than try to plug the gaps with a ‘quick fix’ recruitment initiative” (p 159).
- 4.17. The Government have already taken significant action in this area by introducing pre-initial teacher training (ITT) enhancement courses in physics and mathematics, with a chemistry course following in January 2007. These six-month courses are funded by the Training and Development Agency for Schools (TDA) and allow prospective teachers to undertake intensive subject knowledge training in a subject outside their main specialism, provided they are qualified in that subject to at least A-level standard. According to the Government, “these courses have had high success and low dropout rates” and, of those people completing the physics and chemistry pilot courses in 2004 and 2005, around 85 per cent entered ITT. The Government told us that they were “committed to [the] existing courses for [the] next three years” and intended “to increase the number of places available from 2006” (p 19).
- 4.18. The Institute of Physics was optimistic about the enhancement courses but expressed concern about the financial implications for those people taking them. Whilst the courses themselves are funded by the TDA, they only run from January to June, so prospective teachers can be left without any financial support between June and the commencement of their ITT in September. The Institute noted that participants were ineligible for student loans and suggested that “if a loan structure could be made available, the courses would have significantly more appeal to trainees” (p 52).
- 4.19. Dr Colin Osborne of the Royal Society of Chemistry focused on the importance of persuading sufficient numbers of higher education institutions to offer the enhancement courses. He said that the TDA, attempting to achieve a national roll-out of the courses, was “having great difficulty in finding higher education institutions who wish to participate”. He therefore felt that “there should be a greater inducement for the higher education institutions to run these kinds of courses” (Q 126).

- 4.20. **We welcome the provision of pre-Initial Teacher Training (ITT) enhancement courses in physics, mathematics and chemistry. We recommend that the Government implement a loan system to help participants—especially those with family commitments—to meet their living costs between the end of the course and the commencement of ITT. We also call on the Government to consider further incentives to encourage higher education institutions to participate on enhancement courses.**
- 4.21. The Government are also displaying a willingness to help more non-specialist practising teachers to teach physics or chemistry. The commitment, set out in *Next Steps* and repeated in their written evidence, is to “develop and pilot a ... programme leading to an accredited diploma to give existing science teachers without a physics and chemistry specialism the deep subject knowledge and pedagogy they need to teach these subjects effectively”. Moreover, a remit was given to the School Teachers’ Review Body “to advise on whether science teachers who are not physics and chemistry specialists should receive an incentive” to encourage them to complete the diploma.<sup>34</sup>
- 4.22. Lord Adonis, the Parliamentary Under-Secretary of State, told us that this initiative was being taken forward with the TDA and the National Science Learning Centre, but admitted that “progress at the moment is at a very early stage”. He added that “it is going to take some time before we get the properly accredited diplomas in place” but he hoped to have “something very positive to show this time next year [i.e. June 2007] in terms of a worked up qualification which we can start taking forward” (QQ 43–44).
- 4.23. Asked how the courses might be made attractive to teachers, Lord Adonis pointed to “bursaries and discounted costs ... so that teachers do not have to bear those costs themselves”. In addition, he suggested that if the teachers “see promotion and job opportunities for themselves by this route I think they will find that quite attractive”, particularly in the case of biologists who could “improve their employability in the professions” by gaining a physics qualification (Q 45).
- 4.24. **A clear system of accreditation—accompanied by appropriate rewards—is essential if practising teachers without a physics or chemistry specialism are to be persuaded to give up their time to take courses which will qualify them to teach these subjects more effectively. We recommend that the Government introduce such a scheme as soon as possible.**
- 4.25. The long-term imperative must be to recruit more physics, chemistry and mathematics specialists. A key issue is the availability of the “raw materials”—in other words, the number of graduates in the key shortage subjects. As John Bangs of the NUT told us, “there are not enough graduates (particularly with physics and chemistry degrees) coming out of universities. That is the core problem. Ergo, there are not enough graduates with physics and chemistry degrees going into teaching” (Q 160). The problem is not that physics or chemistry graduates are more averse to a teaching career than graduates in other subjects, but that there are simply not enough graduates in these subjects. In the words of Elspeth Farrar, of Imperial College Careers Service, the percentage of physics graduates going into teaching is in fact

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<sup>34</sup> *Next Steps*, p 45.



“quite a lot higher than the average across all degree areas” (Q 163). Yet if the pool of graduates is too small, there will still not be enough teachers.

- 4.26. This brings us back to some of the issues discussed in Chapters 2 and 3. The key to attracting more students to study science at university is inspiring teaching and effective advice from careers advisers, teachers and parents. The whole process can be a virtuous circle, whereby high quality teaching and advice encourage more students to pursue science, ultimately resulting in a larger pool of talented and highly motivated potential teachers, who can in turn encourage their students to follow in a similar path. Conversely, it can be a vicious circle whereby poor teaching and advice deter students from following science, thus diminishing the pool of graduates and potential teachers, and subsequently having an adverse effect on the next generation.
- 4.27. A further issue is the willingness of students who do opt for science and mathematics degrees to take up a teaching career. According to Professor Jim Donnelly of Leeds University, speaking at our seminar, attractions for potential teachers included working with children, the pleasure of teaching something well, staying with or returning to a favoured subject and a more idealistic desire to “give something back”. Teaching also offered long holidays, particularly attractive to those with families. On the other hand, deterrents included student and parent behaviour, poor salary and career opportunities and adverse working conditions (long hours, poor resourcing, stress and sometimes political interference). Finally, Elspeth Farrar of Imperial College Careers Service claimed that “teaching has lost the status that it once had”, perhaps partly because of “the poor media image of education at the moment” (Q 157).
- 4.28. Student behaviour, workload and status, which potentially affect teachers of all subjects, are longstanding education issues that go well beyond the remit of this inquiry. Pay is also an entrenched problem, though it is of particular relevance to science and mathematics teaching because graduates in those subjects are in such demand across industry and can command high salaries. The Government pointed to TDA research which showed that graduates in shortage subjects “saw themselves as being in a stronger labour market position—with more career choices and potentially more lucrative options”. This particularly applied to potential teachers of mathematics and science, “who were aware from media coverage of their shortage value” (p 18).
- 4.29. Drawing on her experience of careers advice at Imperial College, Elspeth Farrar told us that “many of those students that are doing particularly physical sciences and engineering can attract very high starting salaries, much higher than the starting salaries that are available through teaching. The average starting salary for Imperial graduates who graduated in 2005 was £26,000”. Moreover, “it is not just the starting salaries, it is the progression. Many of those students will go on to careers where they are earning six figure salaries very swiftly” (Q 157).
- 4.30. Financial considerations will be more important for some people than others. However, it would be naïve to imagine that graduates—many with large student debts—and those looking to switch careers would not weigh up the salary prospects of a teacher against alternatives in industry or the city. It would be unrealistic to expect teaching salaries to match those in industry, but an extra few thousands pounds could tip the balance in a potential teacher’s mind in favour of a career which may offer better working conditions and a more fulfilling life. Indeed, the TDA’s new recruitment

campaign for physics and chemistry teachers recognises this point, with the posters focusing largely on the financial inducements available.<sup>35</sup> We cannot therefore agree with Schools Minister Jim Knight MP, who insisted that “teachers are not motivated by more pay ... it is not about pay at all” (Q 32).

- 4.31. The Government have admittedly increased teachers’ pay significantly since 1997, “with a real increase in starting salaries of 11.5 per cent, and up to 17 per cent for those in London”, as well as the additional pay available through the Advanced Skills Teachers scheme (p 19). This is to be welcomed. However, the realities of the marketplace have not been reflected in teacher salaries. In spite of the serious shortage of specialist physics, chemistry and mathematics teachers, and the fact that science and mathematics graduates can often earn substantially more elsewhere than humanities graduates, teachers of those subjects remain on the same salary scale as teachers of any other subject.
- 4.32. This issue was picked up as long ago as 2002, when Sir Gareth Roberts’ report, *SET for success*, recommended that “the Government should tackle ... recruitment and retention problems through increasing the remuneration offered to teachers of these shortage subjects”—namely science, mathematics, ICT and design and technology. Similarly, the Science Learning Centres came to the conclusion that “the only effective way of recruiting extra physical scientists may be to pay them more than other teachers” (p 174).
- 4.33. The Government seem muddled on this issue. Jim Knight rejected the idea of differential pay across the board for teachers of shortage subjects because “there would be a huge deadweight cost” attached (Q 40)—by which he presumably means that higher salaries are not necessary to attract teachers of these subjects in certain schools or areas of the country. Similarly, in written evidence, the Government defended the *status quo*, pointing out that “schools can also make extra payments above the standard pay scales to any teachers for recruitment and retention purposes and decide the amounts themselves” (p 19). However, the Government appear to have recognised that the current situation is not satisfactory, pledging in *Next Steps* to remit the School Teachers’ Review Body to advise on “improving the use of current pay incentives and flexibilities to improve the recruitment, retention and quality of science and mathematics teachers”<sup>36</sup>—a commitment that was reiterated in oral evidence (Q 40).
- 4.34. Amongst the teaching profession itself, there are understandable concerns over the introduction of higher pay for teachers of shortage subjects. John Bangs of the NUT said that “I think all teachers should be paid the same” (Q 174). Similarly, the ASE, whilst welcoming the remit of the School Teachers’ Review Body, warned that “implementation of differential schemes could be divisive within the ... teaching profession” (p 97).
- 4.35. **If the targets for increasing the number of specialist teachers of physics, chemistry and mathematics are to be met, the Government must confront the issue of salaries. Whilst schools already have some flexibility with regard to salaries, the current situation is not satisfactory. We therefore recommend that the Government grant**

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<sup>35</sup> See [http://www.tdanewadvertising.com/uyh\\_posters.htm](http://www.tdanewadvertising.com/uyh_posters.htm).

<sup>36</sup> *Next Steps*, p 45.

**schools a specific right to offer significantly higher starting salaries to candidates specialising in physics, chemistry and other shortage subjects. The Government should simultaneously work to ensure that head teachers are aware of this power and that, where necessary, they make this information available when placing job advertisements.**

- 4.36. The Government have already introduced shorter-term financial incentives in the form of teacher training bursaries and “golden hellos” for postgraduate trainee teachers. Since September 2006 these have been differentiated so that science and mathematics graduates receive a £9,000 bursary and a £5,000 golden hello, whereas graduates in other shortage subjects receive £9,000 and £2,500, and those wanting to teach non-shortage subjects or primary receive a £6,000 bursary only (p 18).
- 4.37. According to the Government, “newly qualified teachers noted the importance of golden hellos in encouraging them to remain in the profession through the first few, sometimes difficult, months—allowing them to develop a more balanced picture of the varying pressures of the profession during the academic year. This was particularly the case for shortage subject teachers who were more aware of the alternative careers open to them” (p 18).
- 4.38. Some witnesses welcomed these incentives. The Royal Society of Chemistry commented, “there can be little doubt that the various initiatives such as training bursaries and ‘golden hellos’ have been successful in attracting people into science teaching” (p 47). Similarly, Professor John Howson of Education Data Surveys cited evidence that the introduction of the training bursaries, on top of the golden hellos, had helped to offset the decline in teacher training applications following the introduction of university tuition fees.
- 4.39. However, a number of witnesses expressed doubts about the incentives. The National Advisers and Inspectors Group for Science (NAIGS) argued that the golden hellos were “not big enough to attract science graduates who could be earning lots more in professions other than teaching” (p 160). John Bangs of the NUT felt that the payments “only have a short-term impact” and suggested that “after two or three years the attractions of a career outside school become overwhelming and the incentive that you originally had to go in disappears” (Q 162).
- 4.40. The Science Learning Centres, pointing out that around two-fifths of newly-recruited science teachers leave before their fifth year of teaching, drew attention to the Teaching and Learning Research Programme’s suggestion that “those who remain as full-time science teachers for four or more years should have their student debt written off” (p 174). The proposed requirement for four years of service is considerably longer than what is required to earn a golden hello. The Institute of Physics agreed that this proposal “could be attractive” (p 52) and the Institution of Engineering and Technology put forward a similar scheme for consideration (p 155).
- 4.41. **Whilst the training bursaries and golden hellos offered to postgraduate trainee teachers appear to have had a positive effect, we are concerned that they may have a fairly short-term impact on the recipient. We call on the Government to examine the merits of reducing the size of the golden hello and offering instead to write off a certain amount of the student debt of new science or mathematics teachers, in return for four or five years of full-time teaching.**

- 4.42. It is equally important to convey to science and mathematics graduates the satisfaction that can be gained from working with children and young people and from teaching them well. The Student Associates Scheme is valuable in this regard, enabling undergraduates to go into a school and gain a “taste” of teaching. Elspeth Farrar of Imperial College told us that students had generally found the scheme to be “very interesting and very useful” and that “a reasonable proportion are carrying on to apply to do a postgraduate certificate in education”. However, she warned that the participating schools “need to be picked very carefully” so that students do not have a “negative experience” (Q 175).
- 4.43. The Government told us that they had agreed to fund the Student Associates Scheme “for a further three academic years from September 2006”. In addition, an extra £700,000 was being made available to expand the number of mathematics and science placements, expected to number around 2,500 in 2006/07. The Government warned, however, that there had been “a degree of reticence” on the part of mathematics and science faculties within certain universities because of “the perceived time constraints on students” (p 25).
- 4.44. Another valuable initiative is Teach First, which enables talented graduates to teach in schools for two years—gaining qualified teacher status so they can remain in teaching or return to it in the future if they wish—and to apply for a job with one of the scheme’s business supporters afterwards. Elspeth Farrar told us that the scheme had been “a very successful way of encouraging students to experience teaching ... [it] has worked very well” (Q 167).
- 4.45. Aside from recent graduates, there is a rich pool of potential teachers amongst those people wishing to change careers and teachers wishing to return to work following a career break. Good use is already being made of the first of these groups: the Government told us that 45 per cent of science teachers and 42 per cent of mathematics teachers had had another career before entering the teaching profession (p 5). Indeed, the Schools Minister, Jim Knight MP, pointed out that “the average age of new teachers coming into the state system is now 30, thanks to ... the number coming in as career switchers in their thirties and forties”. He noted that this was “a transformation on the position even ten years ago ... when virtually all teachers went in doing their PGCE after university and then became lifetime teachers” (Q 28).
- 4.46. Dr Michael Day of the Training and Development Agency for Schools (TDA) illustrated the Agency’s ambition in this area, telling us that “about 85 per cent of the money we spend on recruiting people into teaching is targeted at people who are already in jobs, who are looking for a second job”. These efforts appeared to be paying off: Dr Day noted that teaching had been voted “the most attractive second career by a survey of old graduates” and claimed that the profession was now “very clearly the career of choice for career changers”. The Graduate Teacher Programme, where people can be employed as a teacher whilst doing their training, was targeted in particular at career changers. The scheme had expanded from around 30 participants six years ago to 500 people training to be science teachers in 2004/05 (Q 204).
- 4.47. John Bangs of the NUT was enthusiastic about the Graduate Teacher Programme and its sister scheme, the Registered Teacher Programme, suggesting that they were some of “the best things that have been introduced over the last few years”. However, these routes were still “relatively under-



resourced [and] under-cared for” and needed “good attention”. A particular problem was that people on these schemes “often ... do not get the quality mentoring that they are supposed to get” whereas student teachers attached to higher education institutions tended to get proper support and therefore had “a much higher regard for themselves” as teachers (QQ 181, 183).

- 4.48. The ASE agreed that employment-based routes, especially the Graduate Teacher Programme, had “made a significant contribution to recruitment” but warned that “the incentives, especially for someone who is changing careers, are not generous” (p 96). There may indeed be insufficient incentives to join an employment-based route into teaching, but a more serious problem is that career changers potentially face a move from a relatively senior position to one as an unqualified teacher earning only £14,000 per year. Moreover, those career changers without any teaching experience will face a long training period before their pay can rise to that of a qualified teacher. The danger of insisting that all new teachers must have a formal teaching qualification—even if they have extensive experience in STEM careers—is that, in the words of Elspeth Farrar of Imperial College, they will “choose to go into the private sector because they do not need teaching qualifications” (Q 180).
- 4.49. Admittedly it may not be desirable to pitch career changers straight into full-blown teaching without any training whatsoever. In the words of Dr Derek Bell of the ASE, they “have to demonstrate that [they] can do it”, and this requires more than “simply knowing information”. He pointed instead to “assessment-only routes which are a fast track process for getting in” (Q 204). However, this option may not be suitable for a candidate with no experience of teaching but with extensive knowledge of mathematics or one of the branches of science. Elspeth Farrar proposed “an accelerated scheme” whereby people with “professional experience in industry or commerce” can “gain the QTS quickly” (Q 182). This would allow greater flexibility when preparing new teachers, and might make a move into teaching a more attractive proposition for those with great experience and knowledge to impart.
- 4.50. **We recommend that the Government introduce a modified version of the Graduate Teacher Programme which will allow those with extensive relevant experience of science or mathematics in industry to gain Qualified Teacher Status more rapidly. We further recommend that relevant knowledge and experience should be reflected in a higher salary for career changers commencing their teacher training.**
- 4.51. Many teachers also return to the profession following a career break, particularly those who have taken time off to care for children. As Marie-Noëlle Barton of WISE told us, “women still say that teaching is an excellent career for them if they want to combine a family with a job” (Q 185). The TDA has put significant efforts into tempting such people back to teaching by running a database, providing a telephone helpline and distributing a magazine which is “very heavily targeted at science and maths teachers that have taken career breaks”. In addition, the TDA offers refresher courses which can help teachers returning to the classroom, along with bursaries and childcare allowances. This appears to be paying dividends: Dr Day told us that “about a quarter” of people coming into teaching were returning from a career break (Q 204).



### Teacher retention

- 4.52. Even if sufficient numbers of specialist science and mathematics teachers can be recruited, it is essential that they are subsequently retained. This is necessary not only to maintain teacher numbers, but also to ensure continuity in schools. The importance of such continuity was illustrated by Miriam Rosen of Ofsted, who stated that there was “a clear correlation between higher teacher mobility and less favourable inspection judgements”; she added that “in schools with high teacher mobility the subjects most affected are English, mathematics and science”. Overall, she said, “the proportion of unsatisfactory science teaching was greater in schools with high teacher mobility at 12 per cent compared with five per cent for other schools” (Q 68).
- 4.53. The figures on retention of science and mathematics teachers are mixed. The Government pointed to a study of teachers who qualified in 1994, which showed that just 63 per cent of science teachers and 59 per cent of mathematics teachers were teaching in maintained secondary schools a year later—and these figures had continued to drop consistently over the subsequent ten years. A later survey showed that between 74 and 84 per cent of mathematics teachers and between 72 and 82 per cent of science teachers who attained Qualified Teacher Status in summer 2004 were teaching in the maintained sector six months later. However, the Government also claimed that “retention for mathematics and all sciences has increased since 2002” and that “resignations of science specialists are roughly in proportion with what we would expect compared to the proportion of science specialists in the teaching population”—although more leave the profession altogether, rather than move schools, than the average (pp 22–23). Clearly there is room for significant improvement.
- 4.54. The reasons for teachers leaving the profession tend to be similar to those deterring others from joining in the first place. At the seminar, Professor Jim Donnelly pointed to workload, student behaviour and the weight of Government initiatives as the most problematic issues. Similarly, the Government identified workload, stress, their own initiatives and personal circumstances (p 23). These issues affect all teachers, not just those teaching science and mathematics, and the search for solutions goes well beyond the remit of this report. However, we outline below the main points raised by witnesses and consider what arises from their observations.
- 4.55. Amongst witnesses, student behaviour was the most frequently mentioned of these problems. John Bangs of the NUT told us that “if you have a class or a group of children who are problematic and there is low level disruption ... that will be the straw that breaks the camel’s back. You will go. The trigger is pupil behaviour and that is fairly well documented” (Q 190). Similarly, the Biosciences Federation warned that “feedback from existing teachers in all subject areas shows that lack of discipline in schools is driving experienced teachers from the profession” and added that “there is a danger that accounts of these negative experiences in the media may deter more graduates from entering the profession” (p 65). Both of these outcomes are particularly problematic for those subjects, such as physics and chemistry, which are consistently struggling to recruit sufficient numbers of specialist teachers.
- 4.56. The Schools Minister, Jim Knight MP, told us that Ofsted had reported that “93 per cent of secondary schools have satisfactory behaviour”. In light of the other evidence we have received, it is difficult to know quite what this very

high figure amounts to in reality. Indeed, Mr Knight acknowledged that discipline was “an area where we can do better”. He pointed in particular to behaviour management coaching during teacher training and the measures contained in the Education and Inspections Bill currently going through Parliament (Q 32).

- 4.57. The other problem most often raised by witnesses was the impact of education reform and curriculum change on teachers. On the first issue, the ASE warned that “the plethora of initiatives which face teachers and others adds further confusion resulting in ‘overload’ and potential inertia as schools and teachers attempt to meet the many demands placed on them” (p 100). Similarly, John Bangs referred to “stress and strain about initiatives over which [teachers] have little control” (Q 190). In the Royal Society’s opinion, therefore, “policy-makers must take due account of the effects [of reform] on science teachers by properly consulting with them and their representatives before policies are finalised” (p 60).
- 4.58. On curriculum change, the ASE claimed that “the rate at which system wide change has been, and is being introduced, is becoming counter-productive” and warned that “rarely has there been time to learn from the results of the changes” (p 100). Moreover, Emma Drewery, a science teacher, told us that “teachers have to adapt to the new specifications very quickly, and with little or no support, resources or funding” (p 147).
- 4.59. In order to address retention levels effectively, the Government clearly must work harder to improve behaviour in schools and to minimise the impact of both education reform and curriculum change upon teachers. In addition, they must consult fully with teachers’ representatives at an early stage when formulating new policies. However, the Institution of Engineering and Technology suggested a shorter-term fix in the form of retention bonuses after three, five and ten years for teachers of shortage subjects (p 155). **We call on the Government to ensure that schools have sufficient powers and funds to offer generous retention bonuses to teachers of shortage subjects, and that those schools with retention problems are fully aware of these powers.**

## CHAPTER 5: CONTINUING PROFESSIONAL DEVELOPMENT

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- 5.1. Continuing professional development (CPD) for teachers can broadly be divided into two types—that which improves general pedagogical skills and that which enhances subject knowledge—although there is an important element of interaction between them. In this chapter, we focus on the role of subject-specific CPD for teachers of science and mathematics.
- 5.2. It is widely accepted that CPD is a central component of effective education, but some witnesses were keen to emphasise that subject-specific CPD was of particular importance to science teaching. The Wellcome Trust felt that this “reflects the rapid pace of development in contemporary science; a greater awareness of the social and ethical context within which research is conducted; and advances in information and communications technology, which open up new opportunities for learning” (p 220). Research Councils UK added that “the nature of science means that there is an additional requirement, not relevant to other subjects, which is that science teachers’ CPD also needs to keep them up-to-date on new developments in the field” (p 198).

### Uptake of CPD

- 5.3. Witnesses were gloomy about the level of subject-specific CPD being undertaken by science teachers. Phil Bunyan of CLEAPSS warned that the INSET days, designed to allow teachers to undergo CPD, were “rarely used for subject specific improvement” but were set aside for “general CPD” (Q 209). Moreover, a recent Wellcome Trust survey found that “half of all secondary school science teachers have had no subject-related CPD in the past five years” and that 73 per cent “wanted more subject-relating training” (p 220). Similarly, Ofsted reported that “teachers have told inspectors of the low levels of continuing professional development on science-specific topics” (p 39).
- 5.4. The Wellcome Trust concluded that “there is still not a culture that encourages subject-specific CPD to be viewed as an entitlement” (p 220), whilst the Royal Society suggested that “continuing professional development ... must become a statutory entitlement acknowledged by a fully funded and integrated system of professional recognition”. For example, this could be achieved by “earmarking to subject-specific professional development at least one day of the existing annual teacher INSET entitlement” (p 62). This echoes our recommendation in an earlier report that “regular time must be formally allocated to subject-specific development”.<sup>37</sup>
- 5.5. If there is to be a formal entitlement to subject-specific CPD, it should allow schools maximum flexibility since it is they who are responsible for providing the necessary funding. For example, it may be desirable to allow schools to meet the entitlement by providing in-house subject-specific CPD rather than insisting that all teachers go on an external CPD course every year. However, it would be necessary to provide guidelines to ensure that the entitlement was met with CPD of a sufficiently high quality genuinely to benefit teachers.

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<sup>37</sup> *Science in Schools*, p 8.

- 5.6. Moreover, many schools struggle to find or pay for supply teachers to cover staff undergoing external CPD. As the Campaign for Science and Engineering in the United Kingdom (CaSE) noted, “funding does not exist to provide cover for staff who are away from the classroom, and there is in any case such a shortage of science teachers that even if funds were available, it is not clear that, at present, high-quality cover could be guaranteed” (p 142). Similarly, Dr John Oversby noted that “a major barrier is the lack of supply cover caused by the endemic shortage of science teachers” (p 190) and the Society for General Microbiology commented that “funding for supply cover is an important but often overlooked factor in ensuring that teachers benefit from the in-service training opportunities available” (p 217). One option is to encourage the use of higher level teaching assistants to cover teachers. Alternatively, the Institution of Engineering and Technology called for “regional/local teams of science specialists [to] provide cover across an LEA where required” (p 155). Both solutions carry funding implications.
- 5.7. However, even if a formal entitlement to subject-specific CPD were to be put in place, there is no guarantee that all or even most teachers would make use of the opportunity. Indeed, the Institute of Physics noted that “the teachers most in need of help are the slowest coming forward”. There needed to be “a culture change within the teaching profession, where all teachers feel obliged to engage in professional development” (p 53).
- 5.8. This raises the question of whether it should be mandatory for science teachers to undertake a certain amount of CPD each year. The Biosciences Federation believed that it should be mandatory, since this would ensure that “teachers’ knowledge and understanding of the curriculum stays up-to-date and that their teaching skills are regularly developed, including their ability to teach outside their specialist subject” (p 66). This is a persuasive argument, particularly given that other professionals such as solicitors are required to accrue a certain number of CPD hours each year.
- 5.9. Other witnesses were more wary. Dr Colin Osborne of the Royal Society of Chemistry argued that “mandatory smacks of coercion” and suggested that INSET days had “failed” because of such an approach. Professor Margaret Brown of the Advisory Committee on Mathematics Education (ACME) felt that linking CPD to “the different stages in teaching careers” was a far more “positive” approach than compulsion (Q 136).
- 5.10. However, the Science Learning Centres argued that “incentives for teachers to take part in CPD are not yet embedded in the profession”. Nonetheless, it was felt that “this may slowly change with the introduction by TDA of the new framework of professional standards for teachers” (p 175). Dr Stephen Baker of the TDA reinforced this impression, noting that the proposed new professional standards had “at [their] centre a requirement that teachers remain up-to-date ... with the new developments in ... pedagogy and subject knowledge” (Q 208). Similarly, Julie Bramman of the DfES said that they would “include standards about keeping your subject knowledge up-to-date and showing that you are taking CPD seriously” (Q 48). Indeed, the Government commented, “teachers will need to demonstrate increasing mastery of their subject teaching in order to progress” (p 7). It is thus to be hoped that the new standards will go some way to fulfilling our

recommendation in an earlier report that CPD “should be linked to a clear development structure at all levels of the profession”.<sup>38</sup>

- 5.11. The Government also pointed to the 15<sup>th</sup> report of the School Teachers’ Review Body which “recommended that the outcomes of engagement in professional development be taken into account as part of a range of evidence when schools assess performance for pay progression purposes”, suggesting that “this focus will help to incentivise participation in CPD that makes a positive impact” (p 7). Whilst the wording of this proposal is unnecessarily hedged and vague, we endorse the principle contained therein.
- 5.12. Reflecting this principle, the Government have introduced the Excellent Teacher Scheme, whereby candidates will have to demonstrate—among other things—that they “have developed themselves professionally” in order to qualify for the grade, which comes with a higher salary. Excellent Teachers will be expected to act as role models to other teachers within the school, to share best practice and to help their colleagues to develop their expertise.<sup>39</sup> These functions will in turn be a beneficial source of CPD for teachers.
- 5.13. However, John Bangs of the NUT was wary of the new scheme, claiming that “it has been introduced as a way of capping teachers’ movement up the main scale and capping the costs”. He also felt that there would be confusion between the Excellent Teacher grade and the Advanced Skills Teacher (AST) grade, which differs from the former in that it requires ASTs to provide outreach support to teachers in other schools. In summary, said Mr Bangs, “there is real overlap and confusion” (Q 195).
- 5.14. Another way to encourage teachers constantly to improve the quality of their teaching is to offer accreditation in return for excellence. The Science Learning Centres argued that “a systematic and well-understood framework of professional accreditation would incentivise teachers to engage in CPD, in the way that other professionals such as medics and chartered accountants do” (p 175). The ASE’s Chartered Science Teacher (CSciTeach) scheme provides such a framework, recognising and accrediting excellence in teaching. The criteria for attaining CSciTeach status include having “engaged in, and reflected on, appropriate professional development” and having “work[ed] with colleagues and others in developing science education beyond the classroom”.<sup>40</sup> Moreover, as Dr Derek Bell of the ASE pointed out, those who achieve the status “have to keep up-to-date” and be reassessed every five years (Q 208).
- 5.15. Teachers can be further incentivised if CPD contributes towards a Master’s degree. Dr Michael Day of the TDA told us that “a lot of universities have been looking at changing their PGCE courses, their initial teacher training courses, to give credits on those courses for Master’s degrees”, with teachers being able to add to them “through doing diplomas, certificates or other pieces of work over the first two or three years of their career, which builds up to a Master’s degree”. The TDA would also look at its funding procedures with a view to creating “a continuous programme” for teachers wishing to attain a Master’s degree. However, Dr Derek Bell warned that “a significant number of universities still do not always accept credits from one

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<sup>38</sup> *ibid*, p 7.

<sup>39</sup> See <http://www.teachernet.gov.uk/docbank/index.cfm?id=8482>.

<sup>40</sup> See [http://www.ase.org.uk/htm/thease/csci\\_teach/eis\\_art.pdf](http://www.ase.org.uk/htm/thease/csci_teach/eis_art.pdf).



to another” and argued that “if you have credits, they have to have universal currency” (Q 210).

- 5.16. **Whilst we welcome the Government’s attempts to link continuing professional development (CPD) to career progression, we remain unconvinced that those teachers who could most benefit from subject-specific CPD will take advantage of such opportunities. We therefore recommend that the Government introduce a requirement for all teachers—whatever their subject—to undertake a certain number of hours of subject-specific CPD each year. We further recommend that the Government provide schools with ring-fenced funding for supply teachers to cover staff on external CPD courses, whilst simultaneously giving urgent consideration to how the availability of supply teachers or higher level teaching assistants can be maximised.**

### **Provision of CPD**

- 5.17. We now consider the provision of subject-specific CPD, which can come in many forms. As the ASE commented, it should comprise “a balance of elements including attendance on courses and conferences, time working with colleagues in schools and personal reading and reflection” (p 99).
- 5.18. An additional form of CPD is the sharing of best practice between schools. Indeed, the teachers at Little Heath School, Reading, told us that local cluster groups, enabling teachers to meet on regular occasions to swap best practice, were highly effective vehicles for CPD. Specialist schools in particular are encouraged to act as exemplars to local schools. However, there does not appear to be a formal mechanism for encouraging schools performing poorly in science—or any other subject—to liaise with nearby schools which may be able to offer assistance to teachers. Ian Richardson of Ofsted merely pointed out that “by the publication of our reports we do spread good practice” (Q 81).
- 5.19. **We have already recommended that Ofsted revisit the new subject-specific inspection regime with a view to devising a system which draws evidence from a substantially larger number of schools. Following on from this, we recommend that the Government, along with Ofsted, explore more formal mechanisms to promote contact between schools performing poorly in science or mathematics and better performing schools in the area. This would enable teachers, teaching assistants and technicians to share best practice and to find out how they might improve their performance.**
- 5.20. Subject-specific CPD courses are offered by a range of providers, but the provision of such courses has been boosted significantly by the new network of ten Science Learning Centres (nine regional centres and one national centre in York) funded by the Government and the Wellcome Trust. The latter told us that the centres “provide a network for professional development in science teaching, supporting science teachers and technicians to develop new skills and experiment with innovative techniques”. Over 9,000 training days had been delivered at the centres in 2005 and “the feedback from those who attend has been consistently positive” (p 220).
- 5.21. During our visit to the National Science Learning Centre in York we were highly impressed by the excellent facilities—including well-equipped laboratories and comfortable accommodation for those taking the courses—

and the enthusiasm of the staff. Sitting in on one of the classes for chemistry teachers, it was clear that the courses are an effective means of imparting new ideas and information about science teaching, as well as a valuable opportunity for teachers to meet colleagues from other schools and to discuss best practice techniques. Most courses are in three parts: an initial residential session, a period allowing teachers to put new ideas into practice back in school, and a final residential session. This ensures that teachers gain maximum benefit from the experience. Moreover, attendees are encouraged to stay in touch through the user-friendly web portal.

- 5.22. The Science Learning Centres were generally welcomed by witnesses. The Royal Academy of Engineering felt that they had “laid the foundations for providing a more sustained and comprehensive framework of CPD provision for teachers” (p 200) whilst the Association of the British Pharmaceutical Industry hoped that “all science teachers will be encouraged and supported by the Government, and by their school or college, to attend courses at one of the centres” (p 129). However, Mike Wheale, Head Teacher of Little Heath School, Reading felt that sending staff to the local Science Learning Centre was not necessarily the best use of resources and suggested that the funding should “follow the teacher” as a consumer of training services, rather than going direct to the provider and risking duplication of provision.
- 5.23. The British Ecological Society, whilst supporting the Science Learning Centres, noted that three of six science departments recently approached “did not know what the Science Learning Centres were or their role in the professional development of teachers”. Although this was a small sample, it was felt that “much more effort needs to be placed on marketing this resource to teachers in schools” if the uptake of courses was to be increased (p 138). Greater uptake of courses is essential if the Centres are to be viable.
- 5.24. A more serious issue is the payment of course fees and the cost of providing teacher cover for attendees. As the Wellcome Trust noted, “early indications from teachers attending courses ... are that they can only attend courses if there is external funding to assist with the cost of supply cover and course fees” (p 220). Currently, most attendees at the National Science Learning Centre in fact have their costs met by Wellcome Trust bursaries—provided they can show that their attendance will have a beneficial impact on their school—although teacher cover is not provided. Similarly, the Government provide subsidies to help reduce the fees for those attending the regional centres. However, these subsidies are time limited and it is not clear what will happen after they end.
- 5.25. Dr Derek Bell of the ASE felt that the prospects for the centres were “fairly bleak” once the bursaries have come to an end but the Schools Minister, Jim Knight MP, hoped that “by teachers getting the experience and schools having the experience [whilst the bursaries are in operation] they will then continue to value it” (QQ 209, 49). However, even the core funding for the centres is not guaranteed: the Wellcome Trust has committed to a ten year investment (with reduced funding from year five) for the National Science Learning Centre, whilst the Government have committed funding to the regional centres for the current spending review period. When we pressed Lord Adonis about future funding, he stated that “we will be monitoring the situation very carefully, and ... we will see that will happen in the next spending review” and added that “there are large budgets in the Department

... and I am sure there will continue to be large budgets, so the key priorities will remain key priorities” (Q 53).

- 5.26. **We welcome the new Science Learning Centres, but have serious concerns that they will not be able to attract a sufficient number of attendees once the bursaries have come to an end. We urge the Government to work with the Wellcome Trust to determine how bursaries can continue to be provided in the longer-term, to ensure that the centres are able to flourish.**
- 5.27. The Government have also recently launched the National Centre for Excellence in the Teaching of Mathematics. A “virtual” centre, it is designed “to support, broker and quality assure CPD” and it will “have a role in stimulating demand among teachers” (p 8). The Mathematical Association welcomed the Centre as “an immensely valuable initiative” but warned that “its activities will make little impact unless teachers are given adequate time to engage with what it has to offer” (p 158). Similarly, Professor Margaret Brown of the Advisory Committee on Mathematics Education (ACME) feared that “the time will not be found for teachers to interact with their fellow teachers in their own and local schools” (Q 138). This once again emphasises the importance of providing teachers with an entitlement to a certain amount of subject-specific CPD each year.

## CHAPTER 6: SUMMARY OF RECOMMENDATIONS

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- 6.1. We outlined the key points of our report in the Abstract. In this chapter we set out our conclusions and recommendations in full. The numbers in the brackets refer to the relevant paragraphs in the text.

### Student Attitudes and Choices

- 6.2. There is good evidence that students are opting for “easier” A-levels over the sciences and mathematics, a problem which is compounded by the specialisation forced upon students by the A-level system. We call on the Government to replace A-levels, over the long-term, with a broader-based syllabus for post-16 students. To this end, we suggest that they revisit Sir Mike Tomlinson’s proposals for a diploma system and also consider the International Baccalaureate Diploma Programme. These systems would allow students to maintain greater breadth in their studies, giving them more time to choose the areas which they wish to pursue. They would also result in a more rounded education and would prevent the damage caused by the perception that science and mathematics A-levels are particularly difficult. (2.28)
- 6.3. In general, the Science, Technology, Engineering and Mathematics (STEM) careers advice offered in schools appears not to be of sufficient quality, and the Connexions Service is not well adapted to the needs of high achieving students. The Government have largely neglected careers advice in *Next Steps*, and this omission should be remedied at the earliest opportunity. We recommend that the Government act upon the findings of the Roberts Review by establishing a small central team of advisers to support existing advisers, teachers and parents in making pupils aware of the full range of opportunities and rewards opened up by studying science, mathematics and engineering subjects. (2.41)
- 6.4. The proposed “Careers from Science” website would be a valuable tool in persuading more students to study STEM subjects at A-level and beyond. In light of earlier commitments, the lack of Government assistance to the Science Council is unacceptable. We urge the Government to provide financial and logistical support to the project as a matter of urgency. (2.42)

### Teaching Methods

- 6.5. We do not believe that Ofsted’s new regime for the inspection of individual subjects, based on a small and statistically insignificant sample of schools, will provide sufficiently reliable data on science teaching. We recommend that Ofsted revisit the new subject-specific inspection regime with a view to devising a system which draws evidence from a substantially larger number of schools. We further recommend that subject-specific inspections be carried out by specialists in the subject concerned. (3.7)
- 6.6. We welcome the new science GCSE courses, although it is essential that teachers should maintain the necessary rigour in their teaching and ensure that the “hard” science is retained. However, it is unfortunate that the Government opted to roll out the new courses before the results of the Twenty First Century Science pilot could be fully evaluated, and before the other, unpiloted courses had been sufficiently scrutinised. We recommend that, in future, the Government should allow more time between piloting

new courses and rolling them out across the country. In addition, the Government must keep a very close eye on how the unpiloted courses are bedding down, providing appropriate support where necessary. (3.16)

- 6.7. We welcome the Qualifications and Curriculum Authority's (QCA) plans to align the Key Stage 3 programme of study and the science A-levels with the new GCSEs. However, the introduction of the new A-levels in particular must not be rushed. We recommend that the Government review the proposed timetable for introducing the new A-levels, so as to ensure that there is sufficient time for the new GCSEs to bed down and for teachers to adjust before national roll-out. Furthermore, we call on the Government to ensure that some piloting takes place before the new courses are introduced. (3.19)
- 6.8. Whilst we welcome the existing schemes that bring scientists and engineers into the classroom, particularly the Science and Engineering Ambassadors Programme, we are concerned that academics and university students receive little recognition for helping to inspire the next generation of scientists in schools. We recommend that the Government work with the funding councils to ensure that outreach work in schools is properly valued as part of the RAE, and to encourage higher education institutions to provide details of any such work in their submissions. (3.30)
- 6.9. We welcome the formation of the Regional STEM Support Centres as a means to provide a single, simple source of information on STEM enrichment opportunities. However, the web portal must be comprehensive and accessible. We therefore recommend that there be separate sections for each region, so that the content is tailored to the audience, and teachers and students are thus able to obtain information with the minimum time and effort. (3.35)
- 6.10. We are seriously concerned about the impact that the national testing regime is having upon the teaching of science and mathematics. We call on the Government to ascertain as a matter of urgency how the tests can be altered so as to assess a much broader range of skills, thus allowing the teacher greater flexibility in inspiring students in the classroom. (3.42)
- 6.11. Practical science is at risk in our schools. We urge the Government to take the following action.
  - We call on the Government to review the place of practical science within the national tests as a matter of urgency so as to secure the future of genuinely open-ended, investigative science both inside and outside the classroom. Similarly, the new A-levels should place greater emphasis on practical work, including that outside the classroom or laboratory.
  - We recommend that the Government assess the feasibility of a unified and comprehensive central website dedicated to practical work in all the sciences. Such a website, which could be closely linked to the Science Learning Centres' web portal, should offer health and safety advice and exemplar practicals that can stimulate students.
  - Significant funding is required to remedy the unsatisfactory state of many school science laboratories. We therefore deplore the Government's failure to deliver the £200 million promised for school science laboratories during the 2005 General Election campaign. We welcome the Building Schools for the Future programme, but are



concerned that an insufficient amount of the funding will be spent on improving science laboratories. It is not the role of central Government to determine in detail how schools spend their budgets, but we recommend that the Government, together with local education authorities and Ofsted, initiate a campaign to persuade schools of the huge importance of high quality laboratories.

- The low quality of so many new or refurbished science laboratories is both regrettable and avoidable. We are mystified that the Government, in developing exemplar designs as part of the “School Labs of the Future” programme, have failed to consult acknowledged authorities such as the Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS) and the Association for Science Education (ASE). We recommend that the Government rectify this omission immediately. (3.64)

6.12. A motivated and well-trained supply of technicians is an essential component of effective science teaching. We therefore wholeheartedly endorse the ASE’s proposed career structure for technicians, the new NVQ and the virtual assessment centre. We recommend these proposals to the Government, and in addition invite them to consider whether the career structure could be linked to advisory salary scales, in an attempt to increase the almost universally low level of pay for technicians. (3.72)

### **Teacher Recruitment and Retention**

6.13. We welcome the provision of pre-Initial Teacher Training (ITT) enhancement courses in physics, mathematics and chemistry. We recommend that the Government implement a loan system to help participants—especially those with family commitments—to meet their living costs between the end of the course and the commencement of ITT. We also call on the Government to consider further incentives to encourage higher education institutions to participate on enhancement courses. (4.20)

6.14. A clear system of accreditation—accompanied by appropriate rewards—is essential if practising teachers without a physics or chemistry specialism are to be persuaded to give up their time to take courses which will qualify them to teach these subjects more effectively. We recommend that the Government introduce such a scheme as soon as possible. (4.24)

6.15. If the targets for increasing the number of specialist teachers of physics, chemistry and mathematics are to be met, the Government must confront the issue of salaries. Whilst schools already have some flexibility with regard to salaries, the current situation is not satisfactory. We therefore recommend that the Government grant schools a specific right to offer significantly higher starting salaries to candidates specialising in physics, chemistry and other shortage subjects. The Government should simultaneously work to ensure that head teachers are aware of this power and that, where necessary, they make this information available when placing job advertisements. (4.35)

6.16. Whilst the training bursaries and golden hellos offered to postgraduate trainee teachers appear to have had a positive effect, we are concerned that they may have a fairly short-term impact on the recipient. We call on the Government to examine the merits of reducing the size of the golden hello and offering instead to write off a certain amount of the student debt of new

science or mathematics teachers, in return for four or five years of full-time teaching. (4.41)

- 6.17. We recommend that the Government introduce a modified version of the Graduate Teacher Programme which will allow those with extensive relevant experience of science or mathematics in industry to gain Qualified Teacher Status more rapidly. We further recommend that relevant knowledge and experience should be reflected in a higher salary for career changers commencing their teacher training. (4.50)
- 6.18. We call on the Government to ensure that schools have sufficient powers and funds to offer generous retention bonuses to teachers of shortage subjects, and that those schools with retention problems are fully aware of these powers. (4.59)

### **Continuing Professional Development**

- 6.19. Whilst we welcome the Government's attempts to link continuing professional development (CPD) to career progression, we remain unconvinced that those teachers who could most benefit from subject-specific CPD will take advantage of such opportunities. We therefore recommend that the Government introduce a requirement for all teachers—whatever their subject—to undertake a certain number of hours of subject-specific CPD each year. We further recommend that the Government provide schools with ring-fenced funding for supply teachers to cover staff on external CPD courses, whilst simultaneously giving urgent consideration to how the availability of supply teachers or higher level teaching assistants can be maximised. (5.16)
- 6.20. We have already recommended that Ofsted revisit the new subject-specific inspection regime with a view to devising a system which draws evidence from a substantially larger number of schools. Following on from this, we recommend that the Government, along with Ofsted, explore more formal mechanisms to promote contact between schools performing poorly in science or mathematics and better performing schools in the area. This would enable teachers, teaching assistants and technicians to share best practice and to find out how they might improve their performance. (5.19)
- 6.21. We welcome the new Science Learning Centres, but have serious concerns that they will not be able to attract a sufficient number of attendees once the bursaries have come to an end. We urge the Government to work with the Wellcome Trust to determine how bursaries can continue to be provided in the longer-term, to ensure that the centres are able to flourish. (5.26)

## APPENDIX 1: MEMBERS AND DECLARATION OF INTERESTS

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### Members:

Lord Broers (Chairman)  
 Baroness Finlay of Llandaff  
 Lord Howie of Troon  
 Lord Mitchell  
 Lord Patel  
 Lord Paul  
 Baroness Perry of Southwark  
 Baroness Platt of Writtle  
 Earl of Selborne  
 Baroness Sharp of Guildford  
 Lord Sutherland of Houndwood  
 Lord Taverner  
 Lord Winston  
 Lord Young of Graffham

### Declared Interests:

Lord Broers  
*Fellow, Royal Academy of Engineering*  
*Fellow, Royal Society*  
*Fellow, Institute of Physics*  
*Fellow, Institution of Engineering and Technology*

Baroness Finlay of Llandaff  
*None*

Lord Howie of Troon  
*None*

Lord Mitchell  
*Chairman, eLearning Foundation*

Lord Patel  
*Fellow and Vice President, Royal Society of Edinburgh*  
*Fellow, Academy of Medical Sciences*  
*Chancellor, University of Dundee*

Lord Paul  
*Chancellor, University of Westminster*  
*Chancellor, University of Wolverhampton*

Baroness Perry of Southwark  
*Advisory group for the QCA (Qualifications and Curriculum Authority)*  
*Chair, Quality and Standards Committee of the City and Guilds Institute*

Baroness Platt of Writtle  
*Former President, Association for Science Education*  
*Patron, Women into Science, Engineering and Construction*

Earl of Selborne  
*Director, Sandwell Academy Trust*  
*Fellow, Royal Society*  
*Fellow, Institute of Biology*  
*Patron, INTECH, Winchester*

Baroness Sharp of Guildford

*Governor, Weyfield Community Primary School, Guildford*

*Member, Local Council, Guildford High School*

*Member of the Corporation, Guildford College*

Lord Sutherland of Houndwood

*None*

Lord Taverne

*None*

Lord Winston

*None*

Lord Young of Graffham

*None*

## APPENDIX 2: WITNESSES

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The following witnesses gave evidence. Those marked with a \* gave oral evidence:

- \* Lord Adonis, Parliamentary Under-Secretary of State for Schools, DfES  
Association for Science Education:
- \* Dr Derek Bell  
Association of the British Pharmaceutical Industry
- \* Ms Marie-Noëlle Barton, Director, Women into Science, Engineering and Construction (WISE)  
Dr John Baruch  
Biosciences Federation:
- \* Dr Sue Assinder  
British Association for the Advancement of Science  
British Ecological Society  
British Psychological Society
- \* Professor Margaret Brown, Committee Member, Advisory Committee on Mathematics Education (ACME)  
Campaign for Science and Engineering in the UK  
Confederation of British Industry  
Consortium of Local Education Authorities for the Provision of Science Services:
- \* Mr Phil Bunyan  
Mr Francisco DaCosta  
Mr Tom Dawson  
Department for Education and Skills:
- \* Ms Julie Bramman  
Ms Emma Drewery  
EDU-LAB
- \* Ms Elspeth Farrar, Director, Careers Advisory Service, Imperial College London  
Field Studies Council  
Mr Jules Hoult  
Institute of Food Science and Technology  
Institute of Physics:
- \* Mr Daniel Sandford Smith  
Institution of Engineering and Technology
- \* Mr Jim Knight MP, Minister of State for Schools, DfES  
Professor Hugh Lawlor



Mathematical Association  
National Advisers and Inspectors Group for Schools  
National Endowment for Science, Technology and the Arts  
National Institute for Medical Research  
National Maritime Museum  
National Union of Teachers:  
\*           Mr John Bangs  
Natural History Museum  
Newcastle Science City  
Nuffield Foundation  
OCR  
Ofsted:  
\*           Ms Miriam Rosen  
\*           Mr Ian Richardson  
Dr John Oversby  
Particle Physics and Astronomy Research Council  
Qualifications and Curriculum Authority  
Research Councils UK  
Royal Academy of Engineering  
Royal Armouries  
Royal Astronomical Society  
Royal Meteorological Society  
Royal Society:  
\*           Professor Martin Taylor  
Royal Society of Chemistry:  
\*           Dr Colin Osborne  
Royal Statistical Society  
Salters-Nuffield Advanced Biology  
Science Learning Centres  
Science Museum  
SETNET  
Society for General Microbiology  
Stoke-on-Trent Museum Service  
Training and Development Agency for Schools:  
\*           Dr Michael Day  
\*           Dr Stephen Baker  
Wellcome Trust

### APPENDIX 3: CALL FOR EVIDENCE

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The Select Committee is concerned at the decline in the number of A-level entries in the sciences, and at the impact this may have on the future skill levels of the UK workforce. The inquiry will therefore focus on the role of teachers and teaching methods in physics, biology, chemistry and mathematics from Key Stage 3 to A-level in state schools.

#### The current situation

- The numbers of teachers in physics, biology, chemistry and mathematics, including the numbers teaching outside their specialism.
- Regional variations in the supply of specialist teachers.
- The retention levels for science teachers.

#### Attracting science teachers

- The incentives that exist to attract new graduates and those from other professions.
- Other measures that could be taken to increase teacher numbers.
- The effectiveness of teacher training in science subjects.

#### Teaching science

- The adequacy of professional support for science teachers.
- The effect of changes in the curriculum on attracting/retaining science teachers.
- The impact upon teaching of schemes designed to help generate enthusiasm in young people for science subjects.
- The effect on learning of class size or teaching to single-sex classes.
- The role of the practical in teaching science.

#### Schools

- Variations between schools in the teaching of science, including specialist schools, academies and CTCs; procedures for exchange of best practice.
- The condition of school labs, and provision and use of lab technicians and teaching assistants.
- Links between schools, universities and industry, to facilitate science teaching.

## APPENDIX 4: SEMINAR

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### Wednesday 14 June 2006

Members of the Committee present were: Lord Broers (Chairman), Baroness Finlay of Llandaff, Lord Howie of Troon, Lord Mitchell, Lord Patel, Lord Paul, Baroness Perry of Southwark, Baroness Platt of Writtle, the Earl of Selborne and Lord Taverne. In attendance were Tom Wilson (Clerk) and Dr Cathleen Schulte (Committee Specialist).

### Presentations

Recent Intelligence about the Labour Market for Science and Mathematics Teachers: Professor John Howson

Education Data Surveys' research, which involved close monitoring of the employment market, showed that there continued to be staffing problems in science and mathematics teaching. The advent of university tuition fees had adversely affected the number of teacher training applications up to 2000, but this impact had subsequently been reduced by the introduction of the training grant to supplement the so-called "Golden Hellos".

The projected number of applications this year for Postgraduate Certificates in Education (PGCEs) in the sciences was similar to last year's figure, notwithstanding a very high-profile advertising campaign to attract more teachers. There were, however, fewer applications to mathematics PGCE courses so far. The number of applications and acceptances for PGCEs in both biology and combined sciences had risen steadily over the last ten years, whereas the numbers for chemistry, physics and mathematics had dropped significantly before starting to rise again in the late 1990s, following the introduction of the training grant.

Schools were mostly recruiting general scientists—rather than those with expertise in a particular science—in order to teach general sciences. With regard to pay, most heads of science departments earned only around £8,000 above the normal teaching salary, which was thought to be too low given the extra workload involved.

### *Attitudes to Science Teaching as a Career: Professor Jim Donnelly*

A considerable amount of research had been undertaken into attitudes to science teaching as a career. Attractions for potential teachers included working with children, the pleasure of teaching something well, staying with or returning to the subject in question and a more idealistic desire to "give something back". On a more practical level, teaching was thought to provide long holidays and to fit well with parenting—although these benefits could turn out to be illusory. For particular classes of recruit, teaching offered a good salary and job security. Problems in the supply of physics teachers (the key issue in science teacher recruitment) tended to stem more from the smaller pool of potential entrants than from the distinctive characteristics of physics undergraduates.

Factors that deterred people from pursuing a teaching career included student and parent behaviour, salary and career opportunities and adverse working conditions (long hours, poor resourcing, stress, political interference). There were also difficulties in retaining teachers, with workload, pupil behaviour and Government initiatives being the most common reasons for teachers leaving.

In terms of attracting more new recruits, Government schemes tended to influence those already committed to a teaching career, rather than those inclined not to teach. It was necessary to increase the pool from which science teachers were drawn by improving the curriculum and teaching methods and, in the long term, to ensure that teaching was seen as a properly independent profession rather than a mere tool of Government.

*Recruitment and Retention of Science Teachers, and the impact of new science courses: Mr David Bevan and Ms Sue Flanagan*

New GCSE science curricula would be taught in schools from September 2006. The Twenty First Century Science courses had been piloted in 78 schools and had proved more exciting and relevant for pupils, although the courses were very hard work for teachers and carried serious resource implications.

However, the press had taken an “unhelpful” attitude to the forthcoming GCSE changes and it was therefore vital to show students that the sciences were worth studying beyond the age of 16. The Treasury’s targets for increasing the number of A-level science entries were laudable, but would require a significant increase in teacher numbers.

There was a problem with the “bunching” of new initiatives in science education, with too many things happening at the same time—and it was uncertain whether the Department for Education and Skills was monitoring the situation holistically. It was essential that the changes to the GCSE curriculum be embedded, monitored and evaluated.

*Support and Provision for Practical Science in Secondary Schools: Mr Phil Bunyan*

Less practical work was taking place in science lessons than formerly, and there was less variety. This tended to be because of teachers’ concerns about health and safety—often prompted by mistaken beliefs about which activities were banned—and classroom management. As well as operating a helpline to provide advice on practicals, CLEAPSS offered CPD courses, mostly to technicians but also to some teachers. However, teachers often found it difficult to obtain permission to attend such courses during the week.

Another problem was the state of school laboratories, 41 per cent of which had been classified as “basic (uninspiring)” and 25 per cent as “unsafe/unsatisfactory”. Moreover, it was to be regretted that most technicians were part-time and worked only during school hours, because they rarely had time to carry out the required levels of maintenance on the equipment. It was also unsatisfactory that technicians were not usually included in staff meetings.

## Discussion

There was uncertainty about whether the new GCSE curricula would lead to an increased amount of practical work in schools or, by contrast, whether the new emphasis on ethical and social issues might reduce the frequency of practicals. However, regardless of the effect on practicals, courses like Twenty First Century Science were felt to be an improvement—rather than dumbing down the standard of science education, they would enable a better understanding of the role of science in society. There were, though, concerns that such courses were being introduced before being subjected to full evaluation.

It was important that promising young science students should receive a well-rounded education rather than undergoing “hot-housing” which, while it might

increase the number of people studying science, could do them a disservice in the long-term by narrowing their options too early. Another issue was industry's desire for a greater supply of scientists qualified to a diploma level. Although an engineering diploma was due to be introduced in 2007/8, it was felt to be "rather dull".

Finally, it was noted that there was no requirement—or even entitlement—for teachers to undertake CPD. It was thought that some form of accreditation in return for CPD would be appropriate, and the ASE's Chartered Science Teacher scheme was a step in the right direction. However, it would be difficult to make progress until proper incentives were made available for CPD.

The participants were:

Dr Stephen Baker, Training and Development Agency for Schools (TDA)

Dr Derek Bell, Chief Executive, Association for Science Education (ASE)

Mr David Bevan, Head of Science at Manningtree High School, Essex, and former Chair of the ASE

Mr Phil Bunyan, Director, Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS)

Dr Marianne Cutler, Director of Curriculum Development, ASE

Professor James Donnelly, Professor of Science Education, Leeds University

Ms Sue Flanagan, Deputy Head Teacher at Forest Gate Community School, London, and former Chair of the ASE

Professor Matthew Harrison, Royal Academy of Engineering

Professor John Howson, Director, Education Data Surveys (EDS)

Professor Celia Hoyles, Chief Adviser for Mathematics, Department for Education and Skills (DfES)

Ms Sarah Nairne, DfES

Ms Ginny Page, Education Manager, Royal Society

Dr Almut Sprigade, Research and Information Officer, EDS

Dr Kay Stephenson, Royal Society of Chemistry

## APPENDIX 5: VISIT TO YORK

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### Friday 23 June 2006

Members visiting York were Lord Broers (Chairman), Lord Howie of Troon, Lord Paul, Baroness Perry of Southwark and Baroness Sharp of Guildford, with Tom Wilson (Clerk) in attendance.

#### *Huntington School*

The Committee was welcomed to Huntington School by the head teacher, Mr Chris Bridge. The school was a comprehensive with 1,500 pupils (267 in the sixth form) and a wide ability range. It had been granted technology college status.

Giving a brief introduction, Mr Bridge commented that only one person had applied to become Head of Physics at Huntington School, in spite of its very high reputation, which demonstrated the ongoing difficulties in recruiting science teachers. The number of pupils taking A-levels in science and mathematics had remained stable, even though these subjects had a reputation for being “hard”. Psychology A-level had proved very popular, and two dedicated teachers were employed to teach the course.

The Committee members proceeded to split up into groups in order to talk to students, technicians and teachers, and to sit in on a Sixth Form biology class.

#### *National Science Learning Centre*

The Committee was welcomed to the National Science Learning Centre by Professor John Holman, the Centre Director. The National Centre, which opened in 2005, was funded by the Wellcome Trust until 2013, whilst the nine regional centres were funded by the Department for Education and Skills until 2008. Together, the centres provided professional development services for science teachers, technicians and teaching assistants.

The courses offered at the National Centre were residential, with purpose-built accommodation available on-site. The courses were generally in three parts: an initial residential period where attendees were taught by both internal and external instructors; a “gap task” where new skills could be tried out, with communications being maintained through the web portal; and a second residential period. For the time being, most attendees had their costs met by Wellcome Trust bursaries, provided they could prove that their attendance would have a beneficial impact on their school. However, this subsidy was not sustainable in the medium to long term.

After visiting a class for post-16 chemistry teachers, which looked at the value of discussion groups and games in making chemistry exciting, members took part in a discussion with a number of the Centre’s employees. It was thought to be essential for teachers to receive a sufficient amount of subject-specific continuing professional development (CPD), not merely generic CPD, and that this CPD should consist of a blend of external and in-school training. The value of external CPD was that it allowed teachers to meet colleagues from other schools and to share ideas. There should be a more systematic framework for teacher CPD, as with some other professions, with professional development being linked to pay. The introduction of a system of credits leading to a qualification could also be a valuable development.



The Centre also offered courses on teaching practical science. It was felt that there was not enough exciting practical work in schools for a number of reasons: time pressures, lack of knowledge or confidence among teachers, and a mistaken perception of health and safety constraints. In addition, there were serious problems with the recruitment and retention of science technicians, alongside an inadequate recognition of the importance of their role. Many technicians were part-time, which meant that they often did not have time to carry out valuable preparatory work.

## APPENDIX 6: VISIT TO LITTLE HEATH SCHOOL, READING

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### Friday 30 June 2006

Members visiting Little Heath School were Lord Broers (Chairman), Lord Paul, the Earl of Selborne and Lord Taverne, with Tom Wilson (Clerk) and Dr Cathleen Schulte (Committee Specialist) in attendance.

The Committee was welcomed by Mr Mike Wheale (Head Teacher), Ms Sally Thurlow (Assistant Head) and Ms Tima Lund (Head of Department, Science). Little Heath had been a specialist school in science and mathematics for three years, and its excellence was demonstrated by the exemplary reports from Ofsted.

Mr Wheale emphasised the fundamental importance of recruiting and retaining bright and lively teachers who could offer high quality and enjoyable teaching. Even for a successful school such as Little Heath, where the specialist status was an added draw, it was necessary to work very hard on retention—particularly in a relatively affluent place such as Reading. The cost of housing was a particular problem and the key worker housing scheme, whilst helpful, was fairly complex and limited.

It was felt that market mechanisms already applied to the recruitment and retention of teachers of shortage subjects, in spite of claims to the contrary. Good science teachers were generally paid more, whether through accelerated promotion or other means, to ensure that they were not tempted away by more senior or well-paid jobs elsewhere. On the other side of the coin, Mr Wheale also accepted the potential benefits of recruiting returners or newcomers from industry or elsewhere, although he felt that some of them might find it difficult to adapt to modern teaching methods.

It was suggested that there was a bewildering and unstructured plethora of organisations offering continuing professional development (CPD) for teachers. Whilst some of Little Heath's staff had attended courses at the National Science Learning Centre in York, which had been beneficial, Mr Wheale felt that sending staff on courses at the school's nearest science learning centre (in Southampton) was not necessarily the best use of resources. He suggested that the funding should "follow the teacher" as a consumer of training services, rather than going direct to the providing institution, which risked duplicating training provision at great expense.

Among the science teachers present, there was a feeling that local cluster groups—enabling neighbouring teachers to meet on regular occasions to swap best practice—could be more effective than undertaking CPD at a dedicated institution. In addition, teachers from other schools often came to look at Little Heath which, as a specialist school, was encouraged to act as an exemplar.

With regard to testing, there was a general feeling that the national curriculum tests—far from being onerous—were useful for focusing the minds of students and teachers alike. It was, though, important for teachers to teach the subjects appropriately and not to allow the tests to dominate their methods.

The new GCSE science courses, which were coming into force in September, were welcomed. Little Heath was planning to teach the Twenty First Century Science syllabus. The latter was felt to be more relevant to people's lives whilst retaining plenty of "hard science", thus allowing students to make sensible value judgements about science later in life. The teachers had been on training courses to learn

about the new courses and schemes of work had been purchased—which meant that staff would not have to spend the whole summer preparing. It was felt that not all schools would be able to take such a supportive approach to preparing their science teachers, however. There were also potential difficulties in providing the IT facilities that the new syllabus required.

The condition of school laboratories was a major issue: even Little Heath, a successful specialist school, had some poor quality laboratories in huts. However, the school had cheaply and quickly upgraded a number of laboratories for around £30,000, which was excellent value for money. It was felt that better use of the Government's Targeted Capital Fund would yield impressive results in schools.

Mr Wheale expressed concern that physics, chemistry, mathematics and biology A-levels were harder than other subjects, citing evidence from the Advanced Level Information System (ALIS). Unsurprisingly, this could lead to students spurning science and mathematics A-levels in favour of easier subjects; instead, there ought to be a broad equivalence between subjects.

The Committee were joined by Mr Jeff Trim (Leader, Further Maths Project) and Mr Steve Rayner (Leader, Sixth Form Maths). The mathematics department had achieved very impressive results and, in particular, the high A-level Performance System (ALPS) “value-added” scores demonstrated how high quality teaching was improving students' attainment levels. The students were thought to be encouraged by the dedication of staff, who gave up their own time to help with “Funbus” (an after-school mathematics session with a very high ratio of teachers to students) and to conduct a revision weekend before exams. In addition, the mathematics teachers (along with the science teachers) regularly visited the local feeder primary schools, thus maintaining an excellent liaison between the schools and ensuring educational continuity.

Finally, Mr Trim explained that he was the manager of the Berkshire Further Mathematics Centre, one of 46 across the country. The aim of the centres was to make further mathematics teaching available to any student in the country that wanted it. In its first year, the Berkshire centre had taught 20 students (400 nationally), all from schools where small numbers or lack of staff expertise made further mathematics teaching impossible. Mr Trim did two days work for the centre each week.



## RECENT REPORTS FROM THE HOUSE OF LORDS SCIENCE AND TECHNOLOGY COMMITTEE

Information about the Science and Technology Committee is available on [www.parliament.uk/hlscience/](http://www.parliament.uk/hlscience/), which also provides access to the texts of Reports.

General Parliamentary information is available on [www.parliament.uk](http://www.parliament.uk).

### Session 2002–03

- 1st Report Managing Radioactive Waste: Government Response
- 2nd Report Chips for Everything: Britain's opportunities in a key global market
- 3rd Report What on Earth? The threat to the science underpinning conservation: The Government's response and the Committee's commentary
- 4th Report Fighting Infection
- 5th Report Science and the RDAs: SETting the Regional Agenda

### Session 2003–04

- 1st Report Chips for Everything: follow-up
- 2nd Report Science and the RDAs: follow-up
- 3rd Report Science and Treaties
- 4th Report Renewable Energy: Practicalities
- 5th Report Radioactive Waste Management (*follow-up to 3rd Report 1998-99 and 1st Report 2001-02*)

### Session 2004–05

- 1st Report Science and Treaties: follow-up
- 2nd Report Radioactive Waste Management: Government Response

### Session 2005–06

- 1st Report Ageing: Scientific Aspects
- 2nd Report Energy Efficiency
- 3rd Report Renewable Energy: Practicalities and Energy Efficiency: Government Responses
- 4th Report Pandemic Influenza
- 5th Report Annual Report for 2005
- 6th Report Ageing: Scientific Aspects (Follow-up)
- 7th Report Energy: Meeting with Malcolm Wicks MP
- 8th Report Water Management

# Minutes of Evidence

TAKEN BEFORE THE SCIENCE AND TECHNOLOGY COMMITTEE

WEDNESDAY 28 JUNE 2006

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Present	Broers, L (Chairman)	Platt of Writtle, B
	Howie of Troon, L	Sharp of Guildford, B
	Patel, L	Taverne, L
	Paul, L	

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## Memorandum from the Department for Education and Skills, the Department of Trade and Industry and the Training and Development Agency for Schools on Science Teaching in Schools

### SUMMARY

1. Science and mathematics are priority subjects for the Government. Since the Select Committee's 2001 report about science in schools, the Government has undertaken a substantial programme of action across all aspects of school science and mathematics. These include improving the curriculum, the recruitment of teachers, subject-specific continuing professional development and initiatives to fire young people's interest. In March this year, the Government published *Science and Innovation Investment Framework 2004-14: Next Steps*, which made a number of additional commitments to raise attainment and increase the number of young people continuing to study the physical sciences and mathematics at higher levels.

### INTRODUCTION

2. The future economic success of the UK is dependent upon a good supply of skilled scientists, engineers and technologists. The Government's ambition is to create an education and training environment that delivers the best in science teaching and learning at every stage. It therefore welcomes the priority which the Select Committee continues to give to this area.

3. Since the Select Committee's *Science in Schools* report published in 2001 the Government has invested heavily in school science and mathematics and there are signs that the programme of action it is undertaking is bearing fruit. The Government's *Ten Year Science and Innovation Investment Framework 2004-14*, published in July 2004, made investment in science a priority and stressed its commitment to improving attainment of science, the uptake of science subjects post-16 and the quality of science teachers. The Science, Technology, Engineering and Mathematics (STEM) cross cutting programme was launched last February as part of the 10 year framework and aims to bring better co-ordination and coherence to the many STEM initiatives available, enhance delivery at the front line and support the supply of scientists, engineers and technologists. The Government's response to Professor Adrian Smith's report *Making Mathematics Count* published in 2004 set out a strategy to improve the supply of specialist mathematics teachers, support their professional development and improve the curriculum and assessment framework for mathematics.

4. Key achievements since 2001 have included:

- The establishment of a network of science learning centres, a joint venture with the Wellcome Trust.
- The setting up of a National Centre for Excellence in the Teaching of Mathematics.
- The work of the primary and secondary national strategies, focused on raising attainment.
- The reform of the Key Stage 4 secondary science curriculum to make it more relevant and engaging, while maintaining its breadth, depth and rigour.
- Increasing the number of people training to become teachers by 18 per cent in science and 41 per cent in mathematics from 2001-02 to the present.



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- Reducing the science and mathematics teacher vacancy rate to 0.9 per cent from 1.6 per cent in 2001 and 1.0 per cent from 2 per cent respectively.
- Raising attainment, resulting in 49.9 per cent of young people getting a good science GCSE in 2005 (compared with 48 per cent in 2001) and 52 per cent of young people getting a good mathematics GCSE in 2005 (up from 47 per cent in 2001).
- The establishment of 282 specialist science schools and 222 specialist mathematics and computing schools. We expect a further 10 new specialist science schools and 20 new mathematics and computing schools to be announced before the end of June 2006.
- Creating a network of further mathematics centres. The national network will consist of 46 centres. Some 38 are already open and the remainder will be established by September 2006.
- Increasing the number of science and engineering role models going into schools through the Science and Engineering Ambassadors Programme.
- Inspiring and engaging young people in science, engineering, technology and mathematics through the activities of SETNET, including the participation of 38 schools in an initiative to engage certain Black and ethnic minority pupils in these subjects.

Significant steps forward have been taken to:

- Change the mathematics GCSE from three tier to a two tier assessment to give all pupils potential access to a grade C. This is being introduced for first teaching from September 2006.
- Introduce functional mathematics at GCSE and ensure that when it is introduced in 2010 all pupils who achieve a grade C or above will have mastered the functional elements.
- Develop a second mathematics GCSE for those with an interest in broadening and deepening their understanding of the subject for introduction from 2010.

#### THE GOVERNMENT'S STRATEGY

5. The Government has never been complacent about the scale and nature of the challenges it still faces. In March this year it published *Science and Innovation Investment Framework 2004–14: Next Steps* to increase the level of its ambitions and add a further strong impetus to its drive to achieve them. Chapter 6 covers its plans for school science and mathematics. It addresses the key issues identified by the Select Committee in its present inquiry, namely the recruitment and retention of teachers, the quality of teaching and learning and measures to support and encourage pupils' engagement with and enjoyment of science and mathematics.

6. Central to the Government's programme is reversing the decline in the number of A level entries in the physical sciences and mathematics. The Government shares the Select Committee's and others' concern about declining numbers and is tackling the problems with determination. *Next Steps* announced specific ambitions to achieve year on year increases in the numbers of young people taking A levels in physics, chemistry and mathematics so that by 2014:

- entries to A level physics are 35,000 (currently 24,094);
- chemistry A level entries are 37,000 (currently 33,164); and
- mathematics A level entries are 56,000 (currently 46,037).

Compared with physics and chemistry, the number of A level biology entries is relatively healthy. The Government has, therefore, not set specific targets for this subject.

7. In order to support these ambitions, it will be necessary to improve attainment and progression throughout secondary education. The Government has, therefore, set further ambitions to

- Continually improve the number of pupils getting at least level 6 at the end of Key Stage 3 (11–14 year olds).
- Continually improve the number of pupils achieving A\*-B and A\*-C grades in two science GCSEs.
- Step up recruitment, retraining and retention of physics, chemistry and mathematics specialist teachers so that by 2014 25 per cent of science teachers have a physics specialism (compared to 19 per cent currently), 31 per cent of science teachers have a chemistry specialism (compared to 25 per cent currently) and the increase in the number of mathematics teachers enables 95 per cent of mathematics lessons in schools to be delivered by a mathematics specialist (compared with an estimated 88 per cent currently).

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8. *Next Steps* sets out an ambitious programme of practical commitments to achieve these ambitions, namely to:

- Improve the recruitment, retraining and retention of the science workforce.
- Improve the quality of teaching and learning.
- Strengthen the accountability framework.
- Extend opportunities in science, enabling more young people to fulfil their potential.
- Improve the secondary curriculum.
- Improve progression post-16.
- Improve the physical environment in which science is taught.

9. The £32 million implementation programme over the next two years includes £18 million of new money. This is in addition to the programme to take forward the commitments in the Government's response to the Smith report for mathematics and the support being given to programmes such as the National Strategies and the Science Learning Centres.

#### A LEVEL ENTRIES IN THE SCIENCES AND MATHEMATICS

10. Despite the decline in numbers of young people taking the physical sciences and mathematics A levels, these subjects remain among the most popular subjects at this level.

#### A Level entries for science and mathematics in schools and colleges

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Biology	43,398	47,807	48,897	47,192	46,190	44,592	45,407	43,902	44,235	45,664
Chemistry	34,677	36,613	37,103	35,831	35,290	33,871	32,324	31,065	32,130	33,164
Physics	28,400	28,903	29,672	29,552	28,191	28,031	27,860	26,278	24,606	24,094
Other science	4,194	4,301	4,325	4,124	3,834	3,587	3,740	4,029	3,773	3,779
Mathematics	54,125	56,050	56,589	56,100	53,674	54,157	44,156	44,453	46,017	46,037
Further mathematics	4,913	4,999	5,211	5,145	5,015	5,063	4,498	4,730	5,111	5,192

[Source: SFR01/2006]

11. 70 per cent of 14-year-olds reached at least the expected level for their age (level 5) in science in 2005, compared with 66 per cent in 2001. In mathematics 74 per cent reached level 5 or above last year compared with 66 per cent in 2001.

12. At GCSE 49.9 per cent of young people achieved a good grade (A\*-C) in science last year, compared with 47.6 per cent in 2001. In mathematics 52 per cent got a good grade in 2005 compared with 47.5 per cent in 2001.

13. The Education and Inspections Bill, currently before Parliament, contains provision for a statutory entitlement for pupils to follow a course of study leading to at least two science GCSEs. Subject to Parliamentary approval, the provisions will come into effect from September 2007. The entitlement is intended to protect the route to physics, chemistry and biology A levels.

14. It is the Government's intention that, as now, at least 80 per cent of young people will continue to take at least two science GCSEs. If GCSE science entry levels fall below this target, the Government will take further action to redress the situation. The number of pupils achieving two or more good science GCSEs will be included in the School Achievement and Attainment Tables from 2007.

15. The Government recognises that it will be very challenging to reach the ambitions for 2014 entries, firstly because A level entries in the physical sciences and mathematics have seen a decline over recent years and, in the case of physics, entries are continuing to go down. It will take many years and a substantial and sustained programme of activity to reverse the current position. Secondly, the figures have been set against the background of a downturn in the number of 16–18 year olds, resulting in a 17 year old cohort in 2014 which is some 6 per cent smaller than in 2006. This decline in cohort size means that there will need to be an even larger increase in the proportion of pupils who continue to study A level science. For example, if the cohort size remained the same, 5.4 per cent 17-year-olds would need to take A level physics to hit the target of 35,000 entries, but with the decline in cohort size, 5.8 per cent will need to continue to A level.

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16. The Government made revisions to A level mathematics in 2004 to address some particular specific problems following the Curriculum 2000 reforms. Following these revisions, entries to AS mathematics increased last year by 10 per cent over 2004. The Government will continue to closely monitor the position and consider further measures to ensure A level entries increase year on year.

17. We are creating a network of 46 further mathematics centres. Thirty eight are already open and all 46 centres will be established by September 2006. We expect that the centres will significantly increase the number of entries for further mathematics. Over 400 students are already receiving further mathematics tuition through the centres. There were just under 6,000 entries for further mathematics A level in 2005.

#### IMPROVING THE RECRUITMENT AND RETENTION OF THE SCIENCE WORKFORCE

##### *Recruitment to date*

18. The Government has successfully reversed the decline at the end of the 1990s in mathematics and science teacher recruitment, by a range of factors:

- Introducing training bursaries and, for shortage subjects, Golden Hello payments, with highest rates for mathematics and science.
- Introducing successful advertising campaigns to attract people to take up teaching.
- Encouraged the growth of employment based routes to Qualified Teacher Status, enabling teachers to train while earning in a school, which tends to suit career changers.
- The Training and Development Agency pays training providers an extra £2,000 per mathematics or science trainee they recruit above their 2002–03 baseline.
- Teachers' starting pay has risen in real terms since 1997 by 11.5 per cent for starting salaries (up to 17 per cent in London), and prospects at the top of the main scale have risen 9 per cent (13 per cent in London). There are now more possibilities for higher pay through the Advanced Skills Teacher Scale, and from September the Excellent Teacher grade.
- The Student Associate Scheme and other undergraduate volunteering programmes, designed to attract undergraduates into teaching. In 2006–07 2,500 places on this scheme have been allocated to physics, chemistry and mathematics undergraduates.

*This section summarises key points: Further detail is in the annex*

19. The following tables give figures for science and mathematics recruitment (both conventional courses and employment-based routes) from 1996–97 to 2004–05 which show a 24 per cent increase in science recruitment over the period.

<i>Science</i>	<i>1996–97</i>	<i>1997–98</i>	<i>1998–99</i>	<i>1999–2000</i>	<i>2000–01</i>	<i>2001–02</i>	<i>2002–03</i>	<i>2003–04</i>	<i>2004–05</i>
Conventional ITT places	3,700	3,300	3,050	2,390*	2,690	2,810	2,850	3,225	3,225
Recruitment to conventional courses	2,940	2,790	2,280	2,360	2,410	2,590	2,700	2,870	2,830
Fast Track	—	—	—	—	0	20	20	60	60
Employment Based Routes	0	0	30	60	170	460	520	660	750
Total									
<i>Graduate Teacher Programme</i>	0	0	30	60	160	370	410	470	500
<i>Registered Teacher Programme</i>	0	0	0	0	0	10	10	10	10
<i>Overseas Trained Teacher Teach First</i>	0	0	0	0	10	90	100	150	190
<i>Teach First</i>	—	—	—	—	—	—	—	30	40
Total Recruitment	2,940	2,790	2,310	2,430	2,590	3,080	3,240	3,590	3,640

\* Places in 1999–2000 exclude 300 places under the Maths and Science 600 scheme

Source: TDA ITT Trainee Numbers Census and TDA Employment Based Routes Database

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<i>Mathematics</i>	1996–97	1997–98	1998–99	1999–2000	2000–01	2001–02	2002–03	2003–04	2004–05
Conventional ITT places	2,550	2,250	2,150	1,680*	1,850	1,940	1,940	2,315	2,350
Recruitment to conventional courses	1,650	1,460	1,120	1,300	1,290	1,550	1,670	1,940	2,030
Fast Track	—	—	—	—	0	10	10	20	30
Employment Based Routes	0	0	30	70	120	300	390	570	560
Total									
<i>Graduate Teacher Programme</i>	0	0	30	70	100	220	290	400	370
<i>Registered Teacher Programme</i>	0	0	0	0	0	10	10	10	10
<i>Overseas Trained Teacher</i>	0	0	0	0	10	80	100	120	150
<i>Teach First</i>	—	—	—	—	—	—	—	40	30
Total Recruitment	1,650	1,470	1,150	1,380	1,410	1,860	2,070	2,530	2,620

Places in 1999–2000 exclude 300 places under the Maths and Science 600 scheme

Source: TDA ITT Trainee Numbers Census and TDA Employment Based Routes Database

20. Recruits are not all new graduates. The study *Mathematics and Science in Secondary Schools, The Deployment of Teachers and Support Staff to Deliver the Curriculum*, carried out by NFER for the DfES and published in January 2006, showed that 45 per cent of science teachers and 42 per cent of mathematics teachers had had another career before entering the teaching profession.

21. The rates of vacancies for mathematics and science teachers in secondary schools have also fallen from a peak of 1.6 per cent for science and 2.1 per cent for mathematics in 2001, to 0.9 per cent for science and 1.0 per cent for mathematics in January 2006.

#### *Retention*

22. Typically some 9 per cent of teachers leave the profession a year, mainly due to retirement or death. For teachers who entered teaching in 1994, although slightly more mathematics teachers left in their first year than teachers of other subjects, by 10 years later, the proportions of mathematics, and science teachers remaining was very close to that of all teachers.

23. Training and Development Agency for Schools data shows between 74–84 per cent of mathematics teachers and 72–82 per cent of science teachers who attained Qualified Teacher Status in 2004 were in the maintained sector six months later.

24. Research into why teachers leave the profession cites workload as the main reason (45 per cent said this in 2003)—other factors being stress, “government initiatives” and personal circumstances.

25. The NFER study found the majority of teachers and heads of department under 55 felt they would remain in teaching for the next five years at least. About one tenth expected to leave within five years—which is lower than the wastage level in the 1994 example, which suggests that workload does not amplify the retention problem for mathematics and science.

26. There is some evidence that the age profile of mathematics and science teachers is older than that for all teachers and, within this, 25 per cent of physics degree holding teachers were aged over 50 compared to 15 per cent of biology degree holders. A study for Gatsby has also found that 31 per cent of physics teachers are over 50. The overall age profile of teachers is reflected in teacher supply modelling.

#### *Specialism in mathematics, physics and chemistry*

27. The NFER study quoted above established that although there was no shortage of scientists overall (which the vacancy rate of 0.9 per cent would support), there were shortages of those with physics and chemistry specialisms. They also found a shortage of teachers with a mathematics specialism. (In this report specialism meant being a graduate in that subject, or having studied it during Initial Teacher Training) These shortages were found predominantly in schools with lower than average GCSEs results, higher than average numbers of pupils eligible for free school meals or higher proportions of children with special educational needs. Specialist teachers were unsurprisingly found to a greater extent in 11–18 schools than 11–16. Twenty-six per cent of 11–16 schools had no physics specialists.

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28. The study also considered regional variation and London, the South East and Eastern regions appeared to have fewer physics and chemistry teachers per 1,000 pupils than elsewhere (with Yorkshire also having fewer physics teachers). In mathematics the North East had the fewest specialist teachers per 1,000 pupils.

29. Details are in the annex, but in summary out of about 31,000 secondary science teachers, 92 per cent were science specialists with 44 per cent having an initial specialism in biology, 25 per cent chemistry and 19 per cent physics. Out of 27,400 mathematics teachers 76 per cent were mathematics specialists, 10 per cent had a non-mathematics related specialism and 13 per cent were principally members of other departments.

30. In order to meet the specific ambitions set out in the *Next Steps* document for increase in science specialists, and in the percentage of mathematics lessons taught by specialists, there will need to be further focus on recruitment and retention of mathematics and science teachers. The pool of available graduates is already subject to high levels of competition, so continued activity will be required.

#### *New initiatives to improve recruitment and retention*

31. There are a range of actions being taken which have not yet had time to feed into outcomes for recruitment:

- The introduction of pre-teacher training subject knowledge enhancement courses in mathematics and physics (with plans for chemistry next January).
- A pilot, managed by the TDA, to examine issues associated with the Government's commitment to enable every secondary school to recruit a specialist mathematics and science higher level teaching assistant, by 2007–08 if they wish to, to support qualified teachers.

32. The *Next Steps* document also announced

- Further expansion of the Student Associate Scheme.
- Further expansion of subject knowledge enhancement courses.
- Development of a pilot accredited diploma course to enable more non-specialist teachers to teach physics or chemistry.
- A remit to the School Teachers' Review Body to consider whether there are ways in which existing teachers pay flexibilities could be used better to improve recruitment and retention of science and mathematics teachers.
- A remit to the School Teachers' Review Body to consider whether non physics and chemistry specialists should receive an incentive to complete the accredited training above.
- Extra incentives for providers to recruit physics and chemistry trainee teachers.

### IMPROVING THE QUALITY OF SCIENCE AND MATHEMATICS TEACHING AND LEARNING

#### *The effectiveness of teacher training in science and mathematics*

33. TDA has made significant improvements in ITT quality. In 2000–01 TDA allocations data showed that 63.2 per cent of ITT was undertaken in providers who were rated as being of "high" quality and 35.4 per cent in providers rated as "satisfactory". By 2005–06 the percentage of ITT being undertaken in "high" quality providers had risen to 85.9 per cent and that in "satisfactory" providers had fallen to 8.4 per cent. This was a deliberate strategy by TDA to shift ITT into higher quality providers.<sup>1</sup>

34. TDA's annual Newly Qualified Teacher (NQT) survey measures new teachers' feelings about their training. In 2005 the survey reported that 81 per cent of newly qualified science teachers, and 86 per cent of newly qualified mathematics teachers thought the overall quality of their training was "good" or "very good".

35. In the same year 71 per cent of newly qualified science teachers, and 79 per cent of newly qualified mathematics teachers thought their training had been "good" or "very good" in preparing them to teach their specialist subject. These findings are especially encouraging given that science teachers are expected to teach across all the sciences up to GCSE level.

<sup>1</sup> "High" quality means those ITT providers achieving quality categories A or B in Ofsted inspections; "satisfactory" refers to those achieving quality category C.



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36. ITT provides an increasingly strong foundation, but all teachers (and particularly those in fast-moving subjects such as science) benefit from keeping their pedagogical skills and subject knowledge up to date. TDA therefore believes that it is important for teachers to have access to a combination of deep subject knowledge, initial training, experience, and CPD. Given that some mathematics and science teachers may find themselves teaching outside their subject specialism, TDA believes that there is a strong case for high-level mathematics and science CPD.

37. TDA is driving forward CPD provision by:

- Encouraging demand for teachers' CPD through the review of standards for classroom teachers.
- Working with subject associations.
- Developing CPD programmes such as mathematics for teachers from unconventional backgrounds.
- Managing and developing the Postgraduate Professional Development programme.
- Working with national partners to achieve coherence in CPD.

#### *Stimulating demand for CPD*

38. Continuing professional development is important for all teachers, not just science teachers. Subject-specific CPD must ensure that teachers are up to date and have the specific pedagogical skills to teach their subject effectively.

39. Underlying the new teacher professionalism agenda that is being taken forward with social partners is the aim that professional development should be an ongoing part of the everyday activities of a teacher rather than a separate activity that adds to teacher workload. As part of this agenda a range of reforms is in train to stimulate demand for CPD, including the introduction of revised professional standards for teachers and the introduction of more effective performance management arrangements.

40. The TDA as part of their remit for CPD have provided advice on revised professional standards for teachers that provide a more coherent and progressive career framework which will enable teachers to drive their own careers and determine the professional development they require to make progress, using the standards as a reference point. Expertise in subject knowledge—both up-to-date content knowledge and knowledge of relevant pedagogical approaches—features clearly in the standards. Teachers will need to demonstrate increasing mastery of their subject teaching in order to progress. The standards will include a requirement for teachers to take responsibility for identifying and meeting their own CPD needs which build on self-reflection and commitment to improving their practice. They will also include an expectation that senior teachers and others will have specific responsibility for coaching and mentoring colleagues and supporting their professional development thus strengthening and raising the profile of schools' own "in house" CPD provision. The standards are currently subject to consultation.

41. The introduction of more effective performance management will help to ensure that professional development is planned and evaluated and reflected in assessments of the totality of a teachers' performance and recommendations for pay progression. In their 15 report the School Teachers' Review Body recommended that the outcomes of engagement in professional development be taken into account as part of a range of evidence when schools assess performance for pay progression purposes. This focus will help to incentivise participation in CPD that makes a positive impact.

42. Work is underway to ensure that CPD provision is sufficiently coherent, focused on identified needs and well publicised so as to stimulate and encourage people to consider undertaking CPD activities. The TDA has a remit relating to the overall provision and quality of CPD in the system which should have an impact on quality and quantity of science CPD with both local and national coherence to meet demand:

- The TDA will be working with subject associations to strengthen and promote subject-specific CPD.
- The TDA is currently in discussion with subject associations, including the Association for Science Education (ASE), about chartered teacher schemes that recognise expertise in subject teaching.
- The Agency is conducting a feasibility study with providers of training and development to investigate the value and impact of voluntary quality indicators for the provision of training and development for teachers.
- The TDA intends to continue to expand its Postgraduate Professional Development programme (PPD), using funding criteria to build more partnership models of postgraduate-level CPD provision, and incorporating more federations of schools to increase the relevance of provision.

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- The Agency will focus the revised specification for Returners' Courses on returning teachers meeting the standards for classroom teachers. This will include ensuring that returning teachers are meeting the standards relating to subject knowledge.

43. The introduction and embedding of the revised professional standards and more effective performance management will take place over the next two years. These changes will be key drivers to improve the quality and relevance of CPD.

*Increasing provision of continuing professional development*

44. Alongside these developments, the Government has increased substantially the amount of science and mathematics CPD on offer.

45. The National Strategies are a major provider of science and mathematics CPD. They have developed a variety of blended learning strategies to support science and mathematics staff's CPD such as:

- Subject leader development meetings to develop teaching approaches and provide stimulus and support to subject leaders who can then disseminate to their staff.
- Resources which are self directed (eg science pedagogical pack) which are designed to build capacity for schools to provide their CPD.
- Consultancy support in school in which consultants work over a period of time with staff to develop and improve teaching practice through coaching, mentoring, in-class support and departmental training as appropriate. This is particularly focused on underachieving schools.

46. Recently the Secondary National Strategy has focused its science strand on improving teaching practices in particular areas that pupils and teachers may find challenging. For example, specific knowledge areas like geology or improving particular scientific enquiry skills, such as written scientific explanation and graphical interpretation. They are also providing opportunities for teachers to improve their assessment skills and ability to deal with the demands of improving behaviour in science lessons. In addition, the Strategy has provided support to schools to embed and deliver the new Science GCSE programme.

47. Materials and training from the Strategy have been welcomed by schools and teachers and have been used to great success. Ofsted has recognised the impact of the Strategies' activities on improving teaching and learning in schools and the number of pupils achieving the expected level in science at the end of Key Stage 3 is now higher than ever.

48. CPD for science teachers and technicians is also available through the establishment of the network of 10 science learning centres in a £51 million partnership with the Wellcome Trust. The training focuses on encouraging innovative and exciting teaching practice that will enthuse and inspire young people. All 10 centres are now open and in 2005–06 the regional centres delivered over 11,000 days of training. Feedback from those who have attended courses has been consistently good. It has, however, sometimes been difficult for teachers to take time out of school. Demand is growing among schools for more tailored provision and Centres are responding by offering more bespoke training alongside their published course programmes. An evaluation of science learning centres is underway and an initial report is due this Autumn and final report in December 2007.

49. In response to the Smith report, the Government is setting up a National Centre for Excellence in the Teaching of Mathematics to support, broker and quality assure CPD. It will build on and enhance existing provision as well as identifying gaps and needs and developing appropriate solutions. It will have a role in stimulating demand among teachers. The Centre will be operational from the end of June 2006.

50. In order to improve the teaching of physics and chemistry the Government has decided as part of its *Next Steps* strategy to develop and pilot a CPD programme leading to an accredited diploma. This will give existing science teachers without a physics and chemistry specialism the deep subject knowledge and pedagogy they need to teach these subjects effectively. The Government has recently remitted the School Teachers' Review Body to advise on whether science teachers who are not physics and chemistry specialists should receive an incentive to encourage them to complete physics and chemistry enhancement CPD, leading to an accredited qualification.

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*Improving the quality of teaching and learning*

51. HMCI's 2004–05 annual report says that in secondary schools:

- In Key Stage 3 and on post-16 courses achievement is good in two thirds of schools. There is less good achievement in Key Stage 4.
- Pupils' attitudes to science are generally good, but they are less positive where they are not actively involved through scientific enquiry, making decisions and expressing views. When teaching methods are unvaried and repetitive they become disengaged.
- Teaching is good or better in nearly three quarters of schools and there is very little unsatisfactory teaching. The Key Stage 3 National Strategy has had positive benefits, but more work needs to be done to realise its full potential.
- Overall, assessment practice is good or better in three fifths of schools but the use of assessment to respond to individual needs is good or better in only just over half of schools.
- In four fifths of schools the management and leadership of science is good or better. This is a slight improvement since 1998.

52. The Government's new commitments in *Next Steps* are:

- From 2006, produce a range of case studies which evidence the school level factors associated with high levels of progression to post 16 science and mathematics study and disseminate these through the Secondary National Strategy.
- Ask the Secondary National Strategy to identify and promote effective practice in interactive teaching including imaginative use of practical work.
- Develop a new strand of the Secondary National Strategy focused on support to increase the numbers achieving level 6+ at Key Stage 3.
- As part of the annual reporting on *The Science and Innovation Investment Framework 2004–14* the Government will continue to monitor performance in international benchmarks and will encourage all schools to take part in international assessments.

53. To meet these commitments the Secondary National Strategy will develop and disseminate a variety of guidance and training materials, case studies, self-study packs, classroom activities, lesson plans and other resources to all schools. These materials are aimed at improving pedagogic approaches and teaching practices and Strategy consultants will work with teachers to ensure that the most effective use is made of resources.

54. Additionally, the Department for Education and Skills will continue to participate in and monitor international studies of standards in mathematics and science. We will encourage schools to take part, analyse the results of these studies and use that information to plan follow-up action where appropriate.

#### DEVELOPING THE ACCOUNTABILITY FRAMEWORK

55. The setting of ambitious national targets and the requirement in turn for schools and local authorities to set their own targets for pupils' performance has provided a powerful stimulus for the improvements in educational standards at both primary and secondary level and is helping to eliminate underperformance in schools and narrow the achievement gap for pupils.

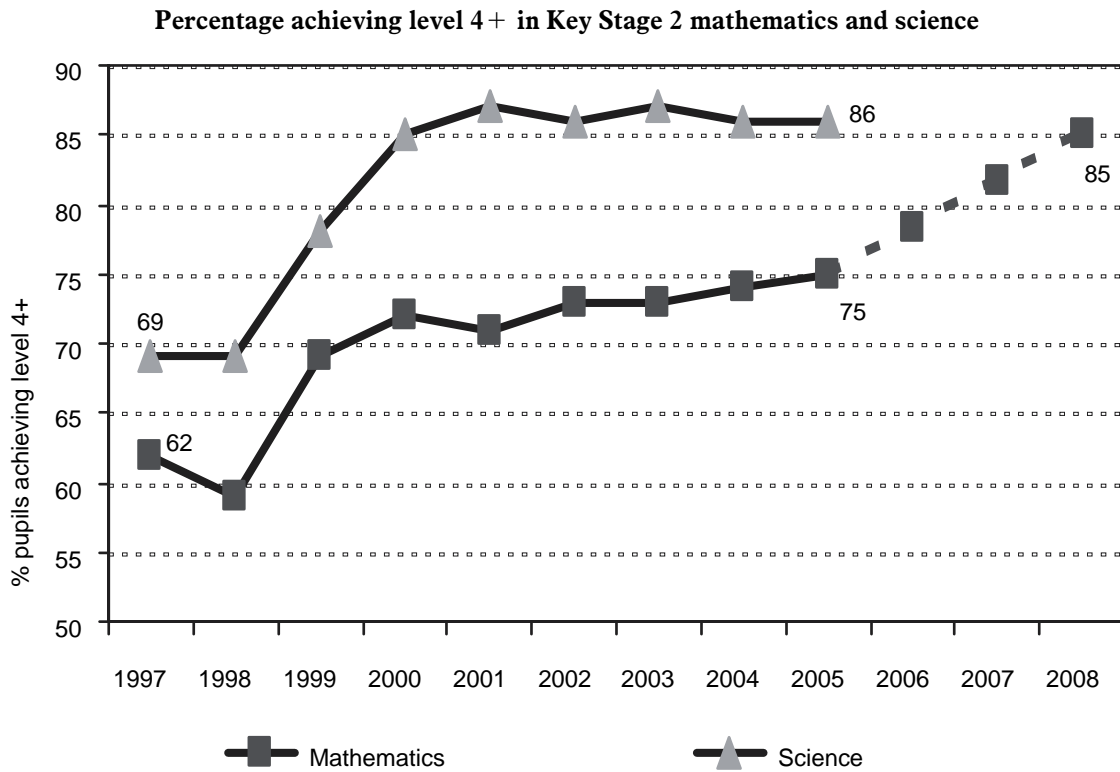
56. Science and mathematics are the focus of two Public Service Agreement targets:

PSA 6: Raise standards in English and mathematics so that:

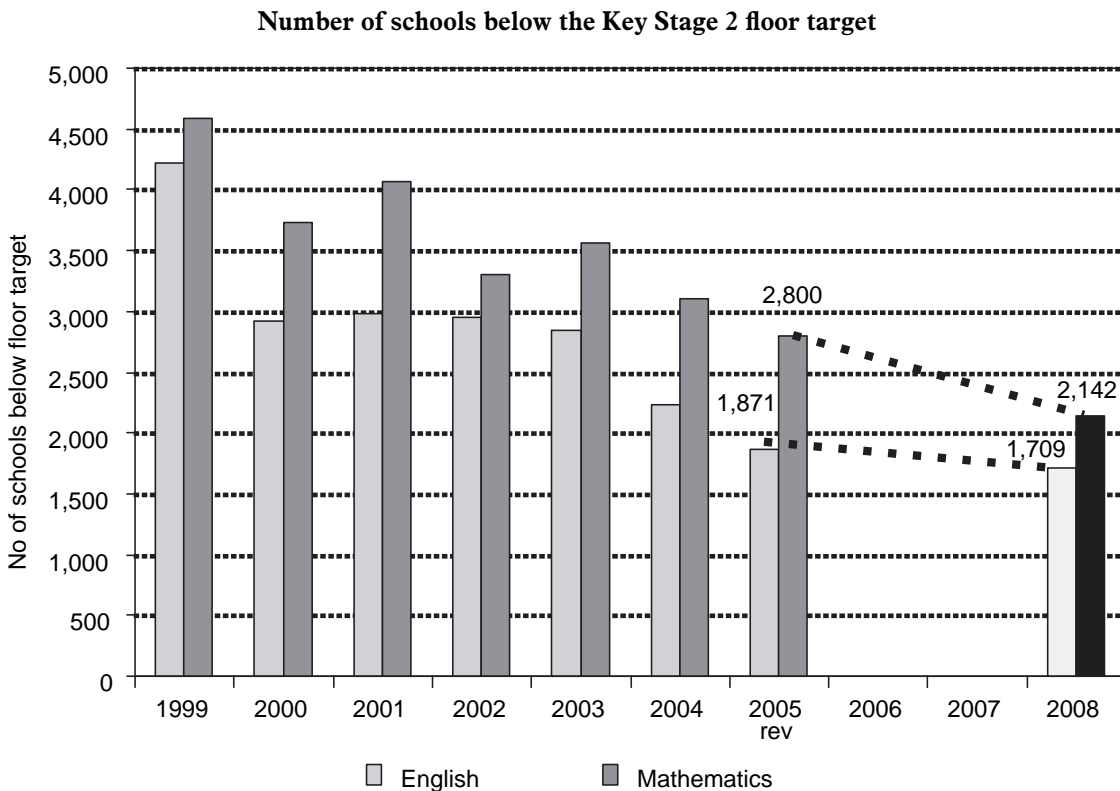
- By 2006, 85 per cent of 11-year-olds achieve level 4 or above, with this level of performance sustained to 2008; and
- By 2008, the proportion of schools in which fewer than 65 per cent of pupils achieve level 4 or above is reduced by 40 per cent.

Key Stage 2 attainment continues to increase in mathematics and there is sustained high performance in science.

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57. The number of schools below the Key Stage 2 floor target (65 per cent Level 4+ in English and mathematics) continues to fall as shown in the graph below.



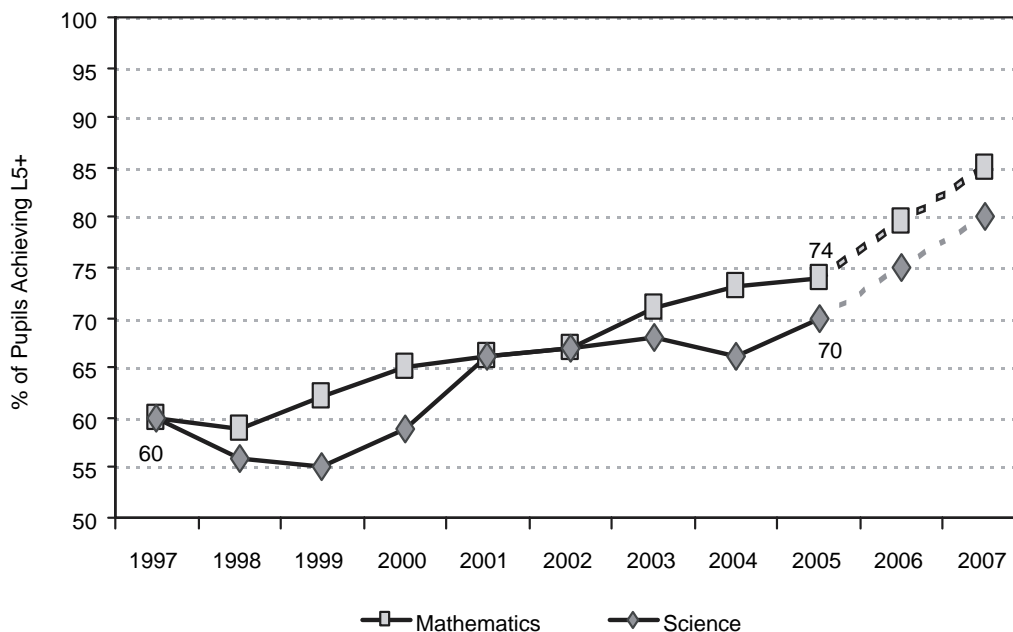
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58. Both mathematics and science are included in PSA7, which is to raise standards in English, mathematics, ICT and science in secondary education so that:

- By 2007, 85 per cent of 14-year-olds achieve level 5 or above in English, mathematics and ICT (80 per cent in science) with this level of performance sustained to 2008; and
- By 2008, in all schools at least 50 per cent of pupils achieve level 5 or above in each of English, mathematics and science.

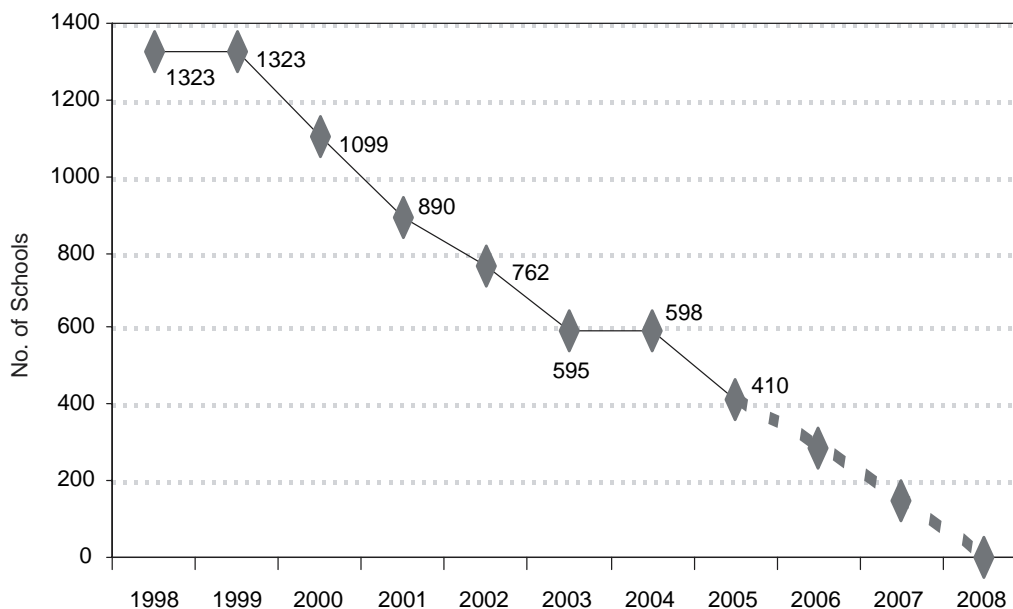
The proportion of 14-year-olds reaching the expected level in Key Stage 3 was at its highest ever in 2005, with 70 per cent of pupils achieving level 5+ in science and 74 per cent in mathematics.

**Percentage of pupils achieving level 5+ in Key Stage 3 mathematics and science**



59. The number of schools below the Key Stage 3 floor target (50 per cent Level 5+ in one or more of the core subjects) continues to fall as shown in the graph below.

**Number of schools below the Key Stage 3 floor target**





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60. The School Achievement and Attainment Tables currently report for each school:

- The percentage of pupils at end of Key Stage 2 achieving level 4 in each of English, mathematics and science.
- The percentage of pupils at end of Key Stage 2 achieving level 5 in each of English, mathematics and science.
- The percentage of pupils at end of Key Stage 3 achieving level 5 and above in each of English, mathematics and science.

From 2006 the Key Stage 3 Tables will show the percentage of 14-year-olds achieving level 6 and above in each of English, mathematics and science. Also a new gold standard indicator will be published in the 2006 Key Stage 4 Achievement and Attainment Tables, showing the percentage achieving five or more A\*-C GCSE (and equivalent) including English and mathematics GCSE.

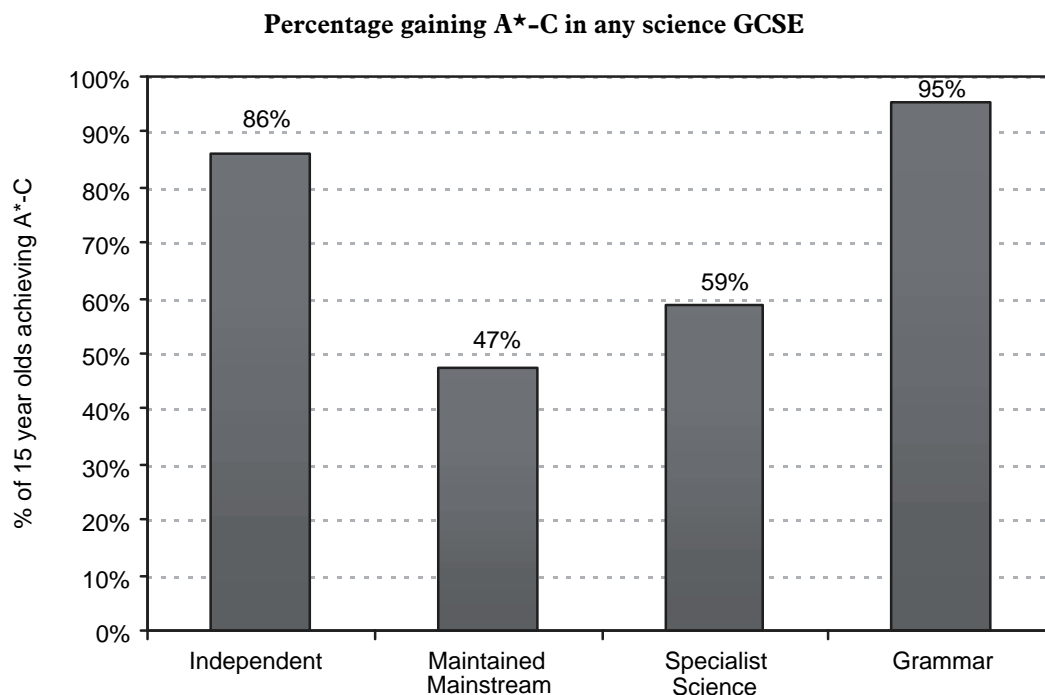
61. The inclusion of science in the school accountability framework is one of the key levers for improving performance in science. *Next Steps* announced proposals to make science a priority in schools using formal accountability mechanisms:

- From 2007 include the percentage of pupils who achieve two or more good (A\*-C) GCSEs in science in or alongside school performance tables.
- Build monitoring of pupil attainment in science into every school's self evaluation and the dialogue with the school's school improvement partner.
- Work with schools to consider ways of getting more transparency around post 16 progression rates so that schools are aware of the importance of students progressing to study A level sciences.

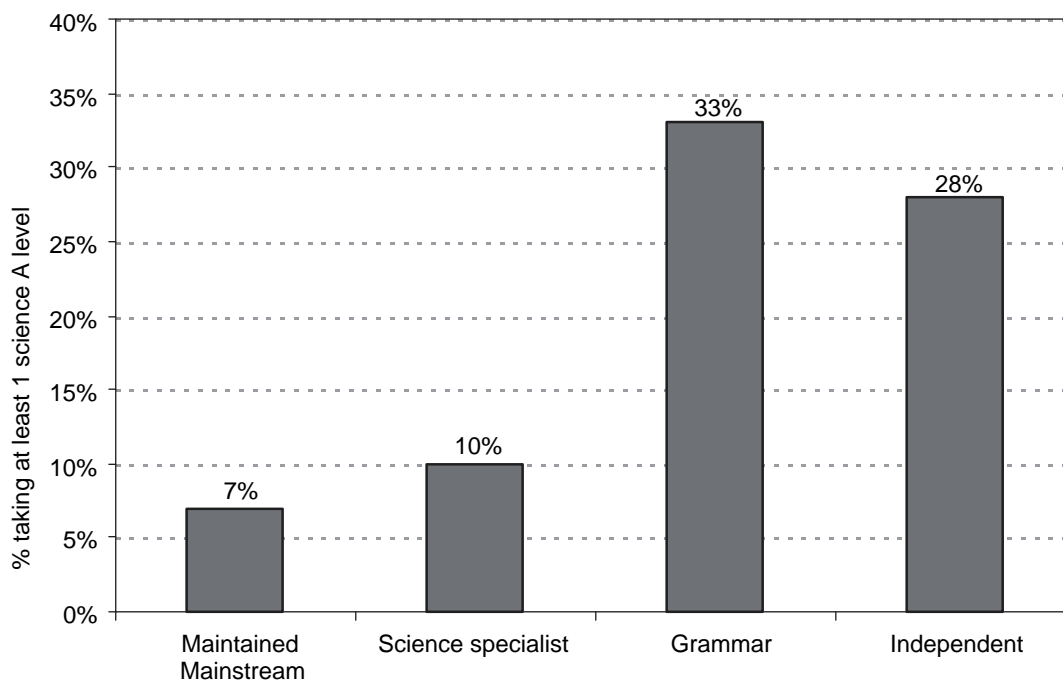
The Government intends to include an indicator showing the percentage of students achieving two or more good science GCSEs in the Achievement and Attainment Tables from 2007 onwards. In addition, we hope to develop an A level progression indicator that can be tested with schools in 2007.

#### EXTENDING OPPORTUNITIES AND IMPROVING PROGRESSION IN SCIENCE

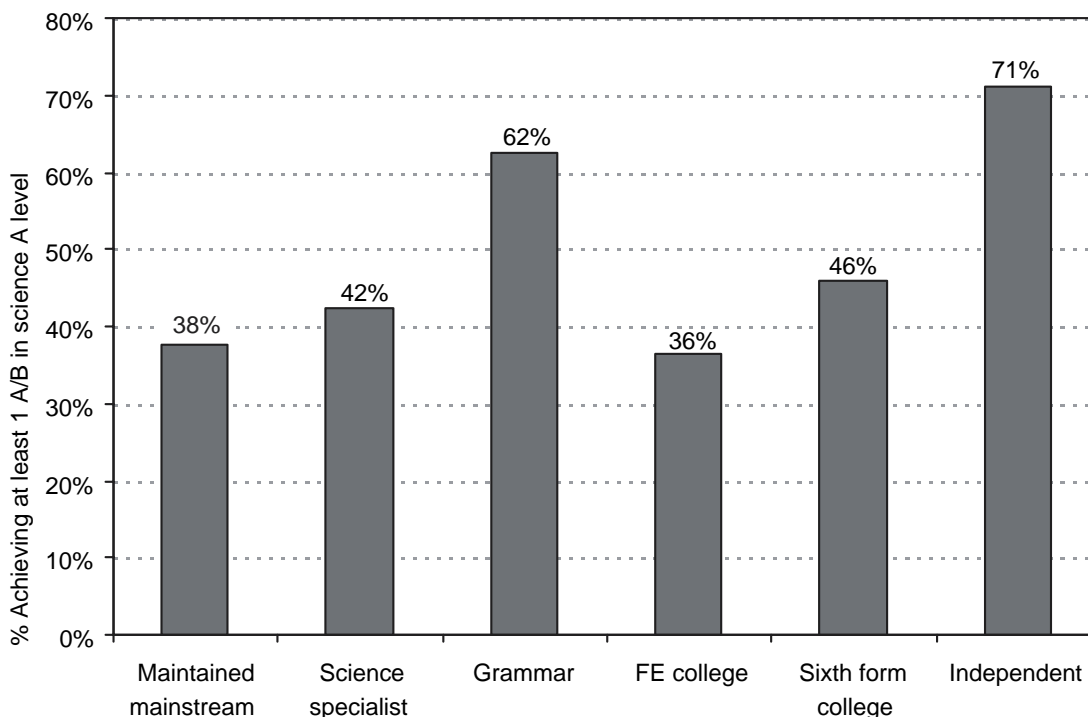
62. There are variations between types of schools in pupils' achievement at GCSE, the percentage of young people who continue studying science to A level, as shown in the graphs below.



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**Percentage of 15-year-old pupils continuing to study at least one science A level**

The percentage of young people who continue to study science A level is higher in grammar and independent schools, however this is mainly due to the differences in attainment at science GCSE as pupils with higher attainment at GCSE are more likely to continue to study science A level.

**Percentage of A level science students who achieve at least one A/B**

63. The Government believes that sharing best practice and working in partnership with schools which have high attainment and progression rates is an important tool for improvement. Working with universities and employers can demonstrate to young people some of the exciting and inspiring opportunities which science and mathematics can lead to. The Government has already done much in this area.

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64. The UK Science Forum was set up in July by the Treasury to engage partners from industry, Government, professional associations and Learned Institutions to further the aims of the *Ten Year Science and Innovation Investment Framework*. The Skills working group of the Forum with, DfES representation, is working with industry and currently looking at improving the channels of communication between education and business to make education more responsive to the needs of the business environment, improving the applied, practical aspects of degrees; and the quality of teaching and learning, particularly in STEM.

65. There are 334 specialist schools with science as one of their specialisms<sup>2</sup> and a further 656 schools with technology or engineering as one of their specialisms. So around 40 per cent of specialist schools have science as a compulsory target setting subject. Around 58 per cent of all specialist schools have mathematics as a compulsory target setting subject including Mathematics and Computing, Business and Enterprise, Engineering, Science and Technology specialist schools. Music and Sports schools may also set targets in mathematics.

66. The Science and Engineering Ambassadors Programme, supported by the Department of Trade and Industry and the Department for Education and Skills, sends 12,000 role models to schools across the UK. Representing a diverse range of individuals: 50 per cent under 35, 38 per cent women and of those who declare their ethnic origin around 15 per cent are non-white; and over 700 different employers, these enthusiastic volunteers go out into all types of schools, inspiring the children and adding to the CPD of teachers. They play a key role in the Government's overall strategy to increase the number of scientists and engineers in the UK workforce and address an increasing skills gap.

67. In *Next Steps* the Government set new commitments to foster greater collaboration and partnership between educational institutions and with employers, and thereby raise pupil attainment:

- Produce guidance and consider the use of financial incentives to encourage schools and Higher Education Institutes, to share resources and expertise with other schools in the area including expanding on existing partnership schemes such as the "Building Bridges Scheme".
- From 2006, the Secondary Strategy and Specialist Schools and Academies Trust (SSAT) to identify and systemise models of effective collaborative working and distribute among schools.
- From 2006 pilot 250 after school science clubs to offer an engaging and stretching programme of activities to Key Stage 3 pupils with interest and potential in science.
- By September 2008 all pupils achieving at least level 6+ at Key Stage 3 to be entitled to study triple science GCSE for example through collaborative arrangements with other schools, FE colleges and universities.
- By September 2008 ensure that all specialist science schools offer triple science at least to all pupils achieving level 6+ at the end of Key Stage 3.
- Encourage all schools to make triple science available to all pupils who could benefit.
- Engage more effectively with employers and universities on how they can help support attainment and progression in science to higher education and science careers through a model of best practice.
- Significantly expand the Science and Engineering Ambassadors scheme to support teachers and engage and enthuse pupils to continue studying science; so that by 2007–08 the total number of ambassadors will be 18,000, an increase of 50 per cent.
- The Government will work with key stakeholders to develop ways to improve the awareness of young people and their parents and teachers of the benefits of studying science and the career opportunities available to those with science, engineering and mathematics degrees and other qualifications.

#### IMPROVING THE SECONDARY CURRICULUM

68. Worldwide, science knowledge is expanding at an unprecedented rate and it is often difficult to predict where the next advances will come. A good science education should ensure that pupils have the skills needed to make sense of new developments. All pupils need a sufficient understanding of science for their role as citizens, now and in the future. Those who will go on to careers in, and related to, science also need a sound preparation for further study and for work.

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<sup>2</sup> 34 have science as a combined specialism and 18 have science as a second specialism.

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69. A new programme of study for science at Key Stage 4 will be introduced in September 2006. It maintains the breadth, depth and challenge of the current curriculum, but has a better balance between knowledge and understanding than the existing curriculum. A considerable amount of support and guidance is already in place to help teachers to introduce the changes. *Next Steps* announced that the Government would be putting in place additional training and guidance. *Next Steps* also announced that the Government would ask the Qualifications and Curriculum Authority to consult scientists as part of its monitoring arrangements for the new Key Stage 4 programme of study.
70. The Qualifications and Curriculum Authority is developing proposals for slimming down the Key Stage 3 science curriculum without reducing the amount of time pupils spend studying science. It will be introduced into schools for first teaching from September 2008. QCA will consider and seek advice from scientists on how the new Key Stage 3 programme of study can stretch the most able pupils.
71. The Government is working with the science learning centres and the Institute of Physics on practical ways to encourage more girls to study physics after the age of 16.
72. The Secondary National Strategy will be identifying and promoting effective practice in interactive teaching including imaginative use of practical work. They will provide schools with guidance on effective interactive teaching and self-study materials collated from best practice examples. They will also develop materials for teachers to use with pupils, which will cover areas such as physical science experiments and aspects of science that pupils find difficult.
73. In line with the recommendation in the Smith report, the three-tier mathematics GCSE will be withdrawn from use in England. It will be replaced with a two-tier qualification for first teaching from September 2006 which is the format used for all other large entry GCSE subjects. The new two-tier qualification will provide all pupils with the potential to achieve C grade. The new specifications are based on the existing Key Stage 4 programme of study.
74. The Government has asked QCA to develop a second mathematics GCSE aimed at both higher achievers and more motivated students in mathematics. This GCSE will be additional to, and free-standing, from the existing mathematics GCSE, with similar content but treated from different perspectives. We envisage that the second GCSE might take a more abstract, structural theoretical perspective—the “why” of mathematics as well as the “how”. The new GCSE should be capable of challenging the brightest students but should not only be accessible to, or of interest to, a small proportion of the cohort.
75. GCSE mathematics is being revised in order to make functional skills an integral part of the learning and assessment. When the revised GCSE is introduced in 2010 no young person will be able to attain C grade or above without mastery of the relevant functional skills.
76. Newly structured A level examinations have been introduced for first teaching from September 2004. The first examination of AS took place last year and the first examinations in A2 are in summer 2006.
77. The University of Leeds and a consortium of Edexcel and King’s College London continue with development work on curriculum and assessment “pathways” models that cover Entry level to level 3 of the National Qualifications Framework, commissioned by the QCA.
78. The Government is creating a national network of Further Mathematics Centres. The national network will consist of 46 centres. Thirty eight are already open and the remainder will be established by September 2006. The centres will not only significantly increase the numbers taking further mathematics, they will also help to promote mathematics to pupils in Key Stage 4 and contribute to the continuing professional development of teachers. Centres will share experience and ideas and publicise the further mathematics network both locally and nationally.

#### IMPROVING THE PHYSICAL ENVIRONMENT IN WHICH SCIENCE IS TAUGHT

79. The Department for Education and Skills collects asset management data from authorities on the sufficiency, suitability and condition of school buildings. There are about 25,000 science laboratories in the 3,400 maintained secondary schools in England. In data received over recent months, authorities suggest that 1,400 more laboratories are needed to meet timetabling and curriculum objectives. For schools generally, the data show significant maintenance needs, but science laboratories are not separately identified. In other respects, 50 per cent of laboratories are not fully suitable because, for example, they are smaller than

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recommended or have lighting/ventilation shortcomings. Of this 50 per cent, teaching methods are adversely affected in two thirds. One in six laboratories has health and safety shortcomings and in a small number of cases, there are serious issues involved. The extent of suitability issues in science laboratories is roughly on a par with other specialist spaces, such as technology and art.

80. HMCI's 2004–05 annual report says that in secondary almost one in six schools has unsatisfactory accommodation for science.

81. 2004 research commissioned by the Royal Society of Chemistry and carried out by the Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS) found that there are around 26,340 science laboratories in maintained secondary schools in England. Of these, only 35 per cent are graded good or excellent. Of the remainder, 25 per cent are considered either unsafe or unsatisfactory for the teaching of science. That is, about 6,560 laboratories ought not to be used, and a further 10,695 are uninspiring to both pupils and teachers. At the same time, teachers report that they need one additional laboratory per school, on average, to be able to teach all science lessons in a laboratory; that is, an under-provision of 3,518 laboratories.

82. The environment in which science is taught can have a major influence on both staff and students. The Roberts Review of 2002 found that suitable science laboratories and equipment are vital to pupils' science education, not only directly (meeting curriculum need) but also indirectly by interesting them and enthusing them to study these subjects further.

83. Capital investment in schools will rise to over £8 billion by 2010–11. This compares to under £700 million in 1996–97. Building Schools for the Future (BSF) aims to renew all secondary schools in fifteen waves of investment starting from 2005–06. The first three waves have already been prioritised and include over 350 schools. We have just announced the arrangements that will apply for the next three waves. We are also providing funding to 38 local authorities, which are in the latter stages of BSF, so that they can rebuild their secondary schools with highest need. In all, by 2010 about a third of all secondary schools will have been allocated funding to rebuild or renew them, including their science laboratories.

84. BSF is, however, only about a third of the total funding available. Schools and authorities continue to receive substantial amounts of funding so that they can address their most urgent needs. A typical secondary school now gets over £100,000 a year to invest in its buildings, and this funding can be added to other resources, or rolled over so that larger projects such as new science laboratories can be tackled. Local authorities are allocated over £1 billion a year for the needs of their schools. This funding supports investment in school laboratories where this is the local priority: the key to promoting better laboratories is raising awareness of the importance of well-designed laboratories and providing examples of good practice.

85. *Next Steps* announced that the Government would review the Building Schools for the Future exemplar designs for school labs to ensure they reflect the latest thinking on what is required to ensure inspiring and effective interactive teaching and learning. This project will develop exemplar designs for science facilities in schools and build a range of demonstration projects in schools across the country which will:

- Fully reflect the requirements of the new science curriculum and innovative pedagogy.
- Support the drive to improve the numbers and quality of young people with science skills by making the teaching and learning of science in schools more attractive and exciting.
- Fully explore the ways in which the whole school building and its grounds, not just the laboratories themselves can enable and enhance innovative and inter-active methods of teaching science.
- Be practical, offer value for money and be within current space, cost and sustainability guidelines and
- Act as “exemplars” for science provision in all future building projects.

**Annex**

## IMPROVING THE RECRUITMENT AND RETENTION OF THE SCIENCE WORKFORCE

### *Recruitment*

1. The Government has increased recruitment of science and mathematics teachers in schools through:

- Conventional initial teacher training: this means a one year PGCE for 95 per cent of recruits or a three year undergraduate course leading to Qualified Teacher Status.

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- Employment-based routes, where graduates go directly into schools and teach from day one, doing their initial teacher training on the job. The Graduate Teacher Programme and Teach First are the main programmes.
- Higher level teaching assistants: a pilot, managed by the TDA, is currently exploring a range of issues associated with the Government's commitment to enable every secondary school to recruit a science and mathematics HLTAs by 2007–08, if they wish to.
- The Student Associate Scheme and other volunteering programmes.

2. The Government introduced the teacher training bursary in 2000 to attract graduates into postgraduate teacher training, and introduced Golden Hellos for those who trained from in September 1999, to attract those who had trained in shortage subjects to take up their first posts teaching those subjects. It increased the value of the teacher training bursary for science and mathematics graduates to £7,000 in September 2005 and for these subjects it will rise again to £9,000 in September 2006. The Golden Hello paid at the end of the induction year for new science teachers rose to £5,000 for trainees entering PGCE and equivalent courses in September 2005.

3. The following tables give figures for science and mathematics recruitment (both conventional courses and employment-based routes) from 1996–97 to 2004–05 which show a 24 per cent increase in science recruitment over the period.

	1996–97	1997–98	1998–99	1999–2000	2000–01	2001–02	2002–03	2003–04	2004–05
Conventional ITT places	3,700	3,300	3,050	2,390*	2,690	2,810	2,850	3,225	3,225
Recruitment to conventional courses	2,940	2,790	2,280	2,360	2,410	2,590	2,700	2,870	2,830
Fast Track	—	—	—	—	0	20	20	60	60
Employment Based Routes	0	0	30	60	170	460	520	660	750
Total									
<i>GTP</i>	0	0	30	60	160	370	410	470	500
<i>RTP</i>	0	0	0	0	0	10	10	10	10
<i>OTT</i>	0	0	0	0	10	90	100	150	190
<i>Teach First</i>	—	—	—	—	—	—	—	30	40
Total Recruitment	2,940	2,790	2,310	2,430	2,590	3,080	3,240	3,590	3,640

\* Places in 1999–2000 exclude 300 places under the Maths and Science 600 scheme

Source: TDA ITT Trainee Numbers Census and TDA Employment Based Routes Database

<i>Mathematics</i>	1996–97	1997–98	1998–99	1999–2000	2000–01	2001–02	2002–03	2003–04	2004–05
Conventional ITT places	2,550	2,250	2,150	1,680*	1,850	1,940	1,940	2,315	2,350
Recruitment to conventional courses	1,650	1,460	1,120	1,300	1,290	1,550	1,670	1,940	2,030
Fast Track	—	—	—	—	0	10	10	20	30
Employment Based Routes	0	0	30	70	120	300	390	570	560
Total									
<i>GTP</i>	0	0	30	70	100	220	290	400	370
<i>RTP</i>	0	0	0	0	0	10	10	10	10
<i>OTT</i>	0	0	0	0	10	80	100	120	150
<i>Teach First</i>	—	—	—	—	—	—	—	40	30
Total Recruitment	1,650	1,470	1,150	1,380	1,410	1,860	2,070	2,530	2,620

\* Places in 1999–2000 exclude 300 places under the Maths and Science 600 scheme

Source: TDA ITT Trainee Numbers Census and TDA Employment Based Routes Database

4. The Teach First programme focuses on recruiting teachers to teach priority subjects in some of London's most challenging schools. Over the three years of the programme, which primarily aims to attract people who had previously not considered teaching as a career, 105 scientists have joined it to teach science, these numbers are included within the EBR totals. The scheme will be expanding to Manchester in September 2006.



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5. There were 210 secondary science teacher vacancies in maintained schools in January 2006, a vacancy rate of 0.9 per cent, which is down from a peak of 1.6 per cent in 2001. There were 190 vacancies for mathematics teachers in January this year, a rate of 1.0 per cent, down from a peak of 2.1 per cent in 2001. The Government is working to reduce these vacancy rates further and ensure that all schools are able to recruit the staff they need to deliver compulsory science and mathematics up to GCSE level, and all schools that wish to offer these subjects post-16 are able to recruit sufficient staff to do so.

6. The NFER study *Mathematics and Science in Secondary Schools, The Deployment of Teachers and Support Staff to Deliver the Curriculum*, carried out by NFER for the DFES and published in January 2006 showed that 45 per cent of science teachers and 42 per cent of mathematics teachers had had another career before entering the teaching profession. In the case of science departmental heads this was 35 per cent and for mathematics departmental heads 32 per cent. In addition to the incentives above, the Government has introduced pre ITT enhancement courses to improve the physics, chemistry and mathematics subject knowledge of graduates from other professions who wish to enter teaching. The first nationally available courses for mathematics and for physics started in January 2006, the first chemistry courses will be from January 2007.

7. The Government, through the TDA, has established a pilot to examine how a sufficient cadre of science and mathematics specialist higher level teaching assistants can be recruited, trained, employed and deployed to enable every school to recruit at least one by 2007–08, should they wish to do so.

#### *Recruitment incentives for trainees*

8. Along with a sustained recruitment campaign, financial incentives have been instrumental in increasing the number of new mathematics and science teachers. Financial incentives are rarely the main reason people are attracted to teaching; instead, they lower financial barriers for those who want to teach but would otherwise be unable to afford to do so.

9. Research undertaken during the Training and Development Agency for Schools' (TDA's) 2005 Review of Financial Incentives indicated that these incentives were of greater importance to trainees with shortage subject backgrounds (including mathematics and science). These trainees saw themselves as being in a stronger labour market position—with more career choices and potentially more lucrative options. They were more interested in assessing the range of financial incentives to become a teacher and were more susceptible to their behaviour being influenced by financial incentives. This particularly applied to potential teachers of mathematics and science who were aware from media coverage of their shortage value.

10. Newly qualified teachers noted the importance of Golden Hellos in encouraging them to remain in the profession through the first few, sometimes difficult, months—allowing them to develop a more balanced picture of the varying pressures of the profession during the academic year. This was particularly the case for shortage subject teachers who were more aware of the alternative careers open to them.

11. The TDA therefore restructured its financial incentives in order to focus on priority subjects where recruitment was most challenging. Whereas in previous years all postgraduate trainee teachers had received the same £6,000 bursary and all priority subjects the same £4,000 Golden Hello, from September 2006 incentives are differentiated by subject. This approach seeks to improve the attractiveness of training to be a mathematics and science teacher, but maintain a degree of equity for primary and secondary non-shortage training. From September 2006 the incentives are differentiated as follows:

- Mathematics and science—£9,000 bursary, £5,000 Golden Hello;
- Secondary shortage subjects—£9,000 bursary, £2,500 Golden Hello;
- Secondary non-shortage and primary—£6,000 bursary.

#### *Incentives for ITT providers*

12. In addition to incentives for trainees TDA has also introduced a range of incentives for ITT providers to recruit more mathematics and science trainees.

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13. ITT providers receive an additional £2,000 per trainee recruited above their 2002–03 academic year baseline. From 2006–07, there will be additional new premiums of £1,000 per trainee to target rewards to all ITT providers who recruit an increasing proportion of their science places in physics and chemistry. Less generous premiums are also in place for biology, so to maintain pressure on the wider drive to improve science recruitment.

14. In each year since these premiums were introduced, there has been improvement in the number of mathematics and science trainees recruited. This demonstrates that, alongside other measures, premiums are an effective tool to boost recruitment and reward providers for going that extra mile.

*Widening the pool of potential mathematics and science trainee teachers*

15. Recruitment pools for trainee mathematics and science teachers are already very heavily exploited, and there is significant competition from other professions, who wish to recruit the same graduates. TDA has introduced initiatives to widen this pool.

16. Pre-ITT enhancement courses have proved a very successful way of expanding the pool of specialist teachers. These courses allow trainees to undertake six months of intensive subject knowledge training and are intended for trainees with mathematics and science-related backgrounds who would like to teach but may not otherwise have the necessary subject knowledge.

17. We have a current programme of physics, chemistry and mathematics enhancement courses. We are committed to existing courses for next three years and the Government has announced its intention to increase the number of places available from 2006.

18. These courses have had high success and low dropout rates and participants are in high demand among schools. Almost 120 people completed physics and chemistry pilot courses in 2004 and 2005. Of these, approximately 85 per cent entered ITT. Around 100 additional participants started courses in January 2006, 60 on physics courses.

19. By developing a range of routes to Qualified Teacher Status (QTS), each tailored to the needs of particular client groups, the TDA have made it easier for people from a wider range of backgrounds to become teachers. This range of routes has increased not only the number of new entrants but also their diversity, and brought into teaching increasing numbers of people with extensive professional and industrial experience.

20. In addition to these mathematics and science-specific initiatives, much of TDA's general recruitment activity has a mathematics and science focus, or devotes significant resources towards these subjects.

21. Teachers' pay has been raised significantly since 1997, with a real increase in starting salaries of 11.5 per cent, and up to 17 per cent for those in London (£19,161 and up to £23,001 in London). Teachers can be awarded additional points on the scales for years of other relevant experience.

22. Prospects are also good, with pay for a good experienced classroom teacher (at the top of the main pay scale) having risen 9 per cent generally, and up to nearly 13 per cent in London (£28,005 and up to £31,749 in London).

23. In addition for high calibre teachers who wish to continue to teach rather than take on management responsibilities Advanced Skills Teachers were introduced, with an obligation to spend one day per week on outreach work helping improve teaching and learning. Their salary scales are drawn from a 27 point scale ranging from £31,491 (£37,782 in Inner London) to £50,238 (£56,526 in London), although from September 2006 their scale will be linked to the leadership pay scale. From 2006 there will also be an Excellent Teacher grade.

24. Schools can also make extra payments above the standard pay scales to any teachers for recruitment and retention purposes and decide the amounts themselves.

*The number of teachers of science and mathematics*

25. The NFER research into the qualifications and deployment of secondary science and mathematics teachers suggests that there are approximately 31,000 science teachers of whom 28,800 are science specialists and 27,400 mathematics teachers of whom 21,100 are mathematics specialists in secondary schools in England. In this study having a specialism was taken to mean holding a degree in or incorporating science or mathematics respectively or specialising in science or mathematics as part of initial teacher training.

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26. The research found that in the 2004–05 academic year 44 per cent of secondary science teachers (13,700 teachers) had an initial specialism in biology, 25 per cent (7,900) had an initial specialism in chemistry and 19 per cent (5,800) had a physics specialism, 5 per cent (1,400) had an initial specialism in another science [or in general science] and 2 per cent of those teaching science had a non-science related initial specialism. Six per cent of those teaching science mainly taught other subjects. The study did not, however, examine the specialisms of the latter category of teachers, so it is not possible to say what proportion had a science specialism. In mathematics the study showed that 76 per cent of mathematics teachers were mathematics specialists, a further 10 per cent had a non-mathematics related specialism and 1 per cent held another qualification. Thirteen per cent of those teaching mathematics were principally members of other departments. In total at least 92 per cent of those teaching science had an initial specialism in science and at least 76 per cent of those teaching mathematics had an initial specialism in mathematics.

#### *Variations by school type*

27. The study showed imbalances in the levels of specialist teachers between types of school by age range and pupil characteristics as well as regional variations. Teachers with a degree in the school sciences, and in particular in chemistry or physics, tended to be more strongly represented in schools with an age range of 11–18 years. Schools with higher than average GCSE results and lower than average numbers of pupils eligible for free school meals tended to have a higher proportion of teachers with a degree in biology, a degree in chemistry and a degree in physics. Schools with lower than average GCSE results, higher than average numbers of pupils eligible for free school meals or with higher numbers of pupils with special needs tended to have a higher proportion of teachers without a post-A level qualification in mathematics.

#### **Distribution of science specialisms by type of school**

<i>Specialism</i>	<i>All schools (N=630)</i>	<i>11–16 schools (N=268)</i>	<i>11–18 schools (N=311)</i>	<i>Other schools* (N=51)</i>
	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>
No biology specialists	1	1	0	0
No chemistry specialists	7	12	4	2
No physics specialists	16	26	10	6

\* Predominately 14–18 schools, though also includes 11–14 schools  
Source: NFER survey of heads of science departments, 2005

#### **Teachers' highest post A level qualification in mathematics by age range and type of school**

<i>Highest post-A-level qualification in mathematics</i>	<i>11–16 %</i>	<i>11–18 %</i>	<i>*Other %</i>
Degree in maths	31	47	47
B.Sc or BA with QTS or B.Ed	20	14	15
Cert Ed incorporating maths	8	5	5
PGCE incorporating maths	20	18	17
Other post-A-level maths qualification	4	5	3
A-Level maths	7	6	4
No post-16 maths qualification	10	6	9
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>

Base: 3,201

\* The “other” category includes schools with 14–18 or 11–14 age ranges due to rounding, percentages may not sum to 100

Source: NFER survey of teachers of mathematics, 2005.

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## REGIONAL VARIATIONS

**Teachers' highest post-A-level qualifications in science by Government Office Region**

Highest post-A-level qualification in science	Government Office Region								
	North East	North West Merseyside	Yorkshire & Humber	East Midlands	West Midlands	Eastern	London	South East	South West
	%	%	%	%	%	%	%	%	%
Degree in Biology	20	26	27	27	25	28	29	27	34
Degree in Chemistry	20	22	14	18	16	13	15	15	13
Degree in Physics	10	10	8	11	9	13	11	11	9
Degree in general science	6	5	6	5	5	6	7	7	4
Degree in other science	14	13	15	15	16	16	16	15	16
B.Sc or BA with QTS or B.Ed in science	14	14	13	10	12	11	10	10	10
Cert Ed incorporating science	9	3	5	6	6	3	2	2	4
PGCE incorporating science	7	5	11	6	6	7	5	6	9
Other post-A-level science qualification	0	<1	<1	<1	2	3	3	4	<1
No post-A-level science qualification	1	1	1	1	3	2	2	3	2
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Base: 2,748

Source: NFER survey of science teachers, 2005.

**Teachers' highest post-A-level qualifications in mathematics by Government Office Region**

Highest post-A-level qualification in science	Government Office Region								
	North East	North West Merseyside	Yorkshire & Humber	East Midlands	West Midlands	Eastern	London	South East	South West
	%	%	%	%	%	%	%	%	%
Degree in maths	37	43	38	45	40	41	47	39	39
B.Sc or BA with QTS or B.Ed in maths	19	17	19	15	18	15	10	16	21
Cert Ed incorporating maths	8	5	8	8	7	6	5	5	5
PGCE incorporating maths	21	19	25	18	16	14	18	17	19
Other post-A-level maths qualification	3	2	1	4	4	7	9	6	3
A-Level maths or no post-16 maths qualification	12	14	9	10	15	18	12	18	14
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Base: 3,204

Due to rounding, percentages may not sum to 100

Source: NFER survey of teachers of mathematics, 2005.

28. No clear pattern emerges of regional differences in the provision of specialist mathematics and science teachers, although mathematics provision shows a greater variation than science. In London, almost half of mathematics teachers' highest post-A-level qualifications in mathematics were degrees. This compares with 37 per cent in the North East Government Office Region. The Eastern and South-East regions have the highest proportion of mathematics teachers whose highest mathematics qualification is either A-level mathematics or who hold no post-16 mathematics qualification. At almost one fifth of teachers, this is twice as high as the level in Yorkshire and the Humber (9 per cent). Considering the teacher provision in the context of pupil numbers, the North East has the fewest specialist mathematics teachers per thousand pupils and the East Midlands has the most.

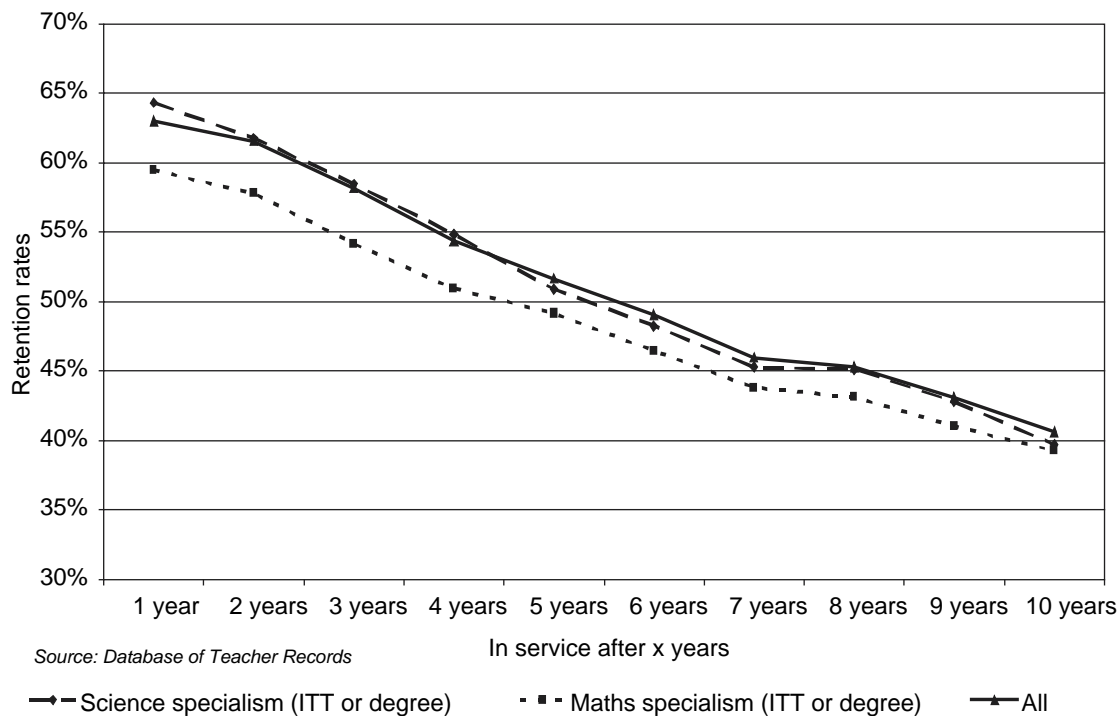
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29. For science, teachers with a degree in science of some sort are relatively evenly spread across the regions and account for the majority of science teachers. However, this hides some imbalances between the sciences: for example, in the South West 34 per cent of science teachers have a degree in Biology compared with only 20 per cent in the North East. It is also clear that in all regions specialist physics provision lags behind that of biology and chemistry. The largest proportions of science teachers without a post-A-level qualification in science are found in the West Midlands and the South East. Considering the teaching provision per thousand pupils shows that biology teachers are evenly spread across the country but the South East, London and Eastern areas show a deficit of physics and chemistry specialists, with an additional physics deficit in Yorkshire and the Humber.

### Retention

30. Typically, some 9 per cent of teachers leave the profession each year, mainly due to retirement or death.

31. The graph below shows retention rates over the last 10 years for those teachers entering service in maintained secondary schools in 1994 and compares teachers with a science specialism or a mathematics specialism with all secondary teachers.



### Retention rates in mathematics and science

32. There are various sources of information about retention of teachers, and they suggest slightly different pictures.

33. The graph shows that, of those that qualified in 1994 just 63 per cent of science teachers and 59 per cent of mathematics teachers were teaching in maintained secondary schools a year later. Over the next 10 years teachers have gradually leaked from the profession. The pattern is very much reflected by teachers of all subjects qualifying in 1994.

34. The Performance Profiles data collected by the Training and Development Agency for Schools suggests a more positive picture. Its survey of those completing ITT shows that between 74 per cent and 84 per cent of mathematics teachers and between 72 per cent and 82 per cent of science teachers who attained QTS in summer 2004 were teaching in the maintained sector six months later.

35. The Employers Organisation also looks at retention rates by subject. They have found that retention for mathematics and all sciences has increased since 2002. There is some variation with mathematics, physics and chemistry mirroring average retention for all subjects in 2003 and 2004 but biology being lower than average.

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However, these rates rely on the Secondary School Curriculum and Staffing Survey (SSCSS) which was last conducted in 2002; therefore these estimates become less reliable over time.

36. One further source of evidence is a series of three research reports, commissioned by the Department for Education and Skills and completed by Alan Smithers and Pamela Robinson. The third of this series<sup>3</sup> suggests that resignations of science specialists are roughly in proportion with what we would expect compared to the proportion of science specialists in the teaching population, although resignations in combined/general science are slightly higher than we would expect. However, when resignations are divided into those moving schools and those leaving the profession, the sciences fare less well with physics, chemistry and biology all exhibiting higher rates of leavers than we would expect. The picture for mathematics is slightly different, with resignations of mathematics teachers being found to be above what we would expect compared to the proportion of mathematics specialists in the teaching population. However, when the resignations are split into movers and leavers the picture varies from year to year. These results are based on a small sample and are not generalisable.

*Why do teachers leave the profession and does this differ for mathematics and science teachers in particular?*

37. Research into “Factors Affecting Teachers’ Decisions to Leave the Profession”<sup>4</sup> identified teacher workload as the primary reason cited by teachers in their decision to leave teaching. This was identified as being “of great importance” for 45 per cent of those leaving the profession during calendar year 2003. The next most commonly cited reasons were stress, government initiatives and personal circumstances. This illustrates that some loss of staff is inevitable and beyond the control of the employer.

38. Linking the importance of workload as a reason for leaving the profession with the finding from the Deployment of Mathematics and Science Teachers project report that around half of mathematics and science teachers and around two thirds of mathematics and science heads of department surveyed expressed dissatisfaction with the hours they spend working, this suggests that there may be a retention problem in science.

39. This tentative conclusion, however, is tempered by two further findings from the Deployment study which found that:

- (a) While few teachers or heads of departments expressed strong satisfaction or dissatisfaction with their job, the majority indicated that they were either neutral or somewhat positive about their work.
- (b) The majority of both teachers and heads of department aged under 55 felt that they were likely to remain in teaching for the next five years at least.

40. Around one tenth of mathematics and science teachers and heads of department felt it very unlikely that they would remain in teaching for the next five years. This is lower than the level of wastage illustrated in the graph above over the same length of time. Although differences in coverage make this comparison difficult, it suggests that workload does not amplify the retention problem of mathematics and science teachers beyond that seen in other subjects.

*Other factors affecting teacher’s decisions to leave the workforce*

41. There is some evidence to suggest that the mathematics and science teaching population—and the physics teaching population in particular—has a slightly older age distribution than the teaching population in general. The 2002 Secondary School Curriculum and Staffing Survey (SSCSS) considered the age of full-time teachers and the subject of their highest post-A-level qualification. It concluded that mathematics, physics and chemistry had a higher proportion of teachers aged 50 and over than the teaching population as a whole. This proportion had shown a significant increase since the previous survey in 1996, but this increase was in line with the general ageing of the teaching population: a known pattern and one which is considered in detail in the modelling of future demand.

42. The NFER study findings from 2005 concurred with the 2002 SSCSS, suggesting an age profile of mathematics teachers similar to that of the whole population and a science profile which looked slightly younger than all teachers. However, this masked variations within the sciences, and the NFER study found

<sup>3</sup> “Teacher Turnover, Wastage and Movements between Schools”, Smithers and Robinson, DfES, 2005. <http://www.dfes.gov.uk/research/data/uploadfiles/RR640.pdf>

<sup>4</sup> “Factors Affecting Teachers’ Decisions to Leave the Workforce”, Smithers and Robinson, DfES, 2003. <http://www.dfes.gov.uk/research/data/uploadfiles/RR430.pdf>



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in particular that one quarter of teachers holding a physics degree were aged over 50, compared to just 15 per cent of biology degree-holders.

43. More recently, the research for the Gatsby Foundation into physics teachers found even more skewed results, with an estimated 31.1 per cent of physics teachers aged over 50 compared to 16.6 per cent aged 30 and under.

44. The interaction between age, sex and wastage is relatively complicated. For example, we know that men and women leave the profession for different reasons and at different times, depending on both personal and economic factors.

45. The NFER research found that the age range for science and mathematics teachers and heads of department was as follows:

#### Age range of science teachers and heads of department

Age range	Science teachers		Heads of science departments	
	N	%	N	%
Under 25	143	6	0	0
25–29	509	20	31	5
30–39	707	27	222	32
40–49	624	24	223	32
50–59	580	22	213	31
60+	34	1	5	<1
<b>Total</b>	<b>2,597</b>	<b>100</b>	<b>694</b>	<b>100</b>

No response: 159 science teachers; 60 heads of science departments

Due to rounding, percentages may not sum to 100

Source: NFER science teacher survey and science head of department survey, 2005

#### Age range of mathematics teachers and heads of department

Age range	Mathematics teachers		Heads of mathematics departments	
	N	%	N	%
Under 25	150	5	1	<1
25–29	444	15	26	4
30–39	749	25	221	31
40–49	779	26	240	33
50–59	857	28	232	32
60+	57	2	5	<1
<b>Total</b>	<b>3,036</b>	<b>100</b>	<b>725</b>	<b>100</b>

184 mathematics teachers and 48 heads of department made no response to this question

Due to rounding, percentages may not sum to 100

Source: NFER surveys of teachers of mathematics and heads of mathematics departments, 2005

46. *Next Steps* sets out the Government's strategy to:

- Remit the School Teachers' Review Body (STRB) to advise on improving the use of current pay incentives and flexibilities to improve the recruitment, retention and quality of science and mathematics teachers. Evidence is currently being compiled for submission to the STRB to back up the remit letter which was sent on 17 May.
- From 2006 continue the drive to recruit science graduates into teaching via Employment Based Routes with new incentives for providers of £1,000 per recruit to attract more physics and chemistry teachers.
- From 2006 offer additional courses to enhance physics, chemistry and mathematics subject skills for those entering teaching who do not have a recent degree in the subject.

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- Expand the Student Associates Scheme to give science and mathematics students at university a taste of teaching with a view to encouraging them to pursue teaching as their career. In March 2006, the Government agreed to fund the Student Associates Scheme for a further three academic years from September 2006. In March the Chancellor also announced that he was making a further £700,000 available to expand the number of mathematics and science placements on the scheme for 2006–07 and 2007–08. For 2006–07, we expect the TDA to expand the number of mathematics and science placements to around 2,500—the exact proportion for mathematics and science will not be known until the TDA’s tender process for providers has been completed in August 2006. These are challenging targets which will require an increase on previous years on the numbers of HEIs participating in the scheme and better access to mathematics and science faculties within HEIs, where there has been a degree of reticence in the past about engaging with the scheme, because of the perceived time constraints on students.

#### IMPROVING THE QUALITY OF SCIENCE AND MATHEMATICS TEACHING AND LEARNING

##### *The effectiveness of teacher training in science and mathematics*

47. TDA has made significant improvements in ITT quality. In 2000–01 TDA allocations data showed that 63.2 per cent of ITT was undertaken in providers who were rated as being of “high” quality and 35.4 per cent in providers rated as “satisfactory”. By 2005–06 the percentage of ITT being undertaken in “high” quality providers had risen to 85.9 per cent and that in “satisfactory” providers had fallen to 8.4 per cent. This was a deliberate strategy by TDA to shift ITT into higher quality providers.<sup>5</sup>

48. TDA’s annual Newly Qualified Teacher (NQT) survey measures new teachers’ feelings about their training. In 2005 the survey reported that 81 per cent of newly qualified science teachers, and 86 per cent of newly qualified mathematics teachers thought the overall quality of their training was “good” or “very good”. In the same year 71 per cent of newly qualified science teachers, and 79 per cent of newly qualified mathematics teachers thought their training had been “good” or “very good” in preparing them to teach their specialist subject. These findings are especially encouraging given that science teachers are expected to teach across all the sciences up to GCSE level.

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<sup>5</sup> “High” quality means those ITT providers achieving quality categories A or B in Ofsted inspections; “satisfactory” refers to those achieving quality category C.

#### Examination of Witnesses

Witnesses: MR JIM KNIGHT MP, a Member of the House of Commons, Minister of State for Schools, LORD ADONIS, a Member of the House, Parliamentary Under-Secretary of State for Schools, and MS JULIE BRAMMAN, Head of Curriculum, Specialism and Collaboration, DfES, examined.

**Q1 Chairman:** Good afternoon and thank you very much, Mr Knight, Lord Adonis and Ms Bramman, for coming to talk to us. I am sure you are aware that this is a short follow-up inquiry which the Committee is pursuing. There is, for the sake of the public, an information note outside. I hope we can proceed smoothly this afternoon. I understand there may be divisions in both Houses, so we will hope for a smooth run and that we do not get interrupted. We can go straight into the questions, if you like, but I think it would be useful if you each introduced yourselves, please.

*Jim Knight:* Jim Knight MP, Minister of State for Schools and 14 to 19 learners.

*Lord Adonis:* Andrew Adonis, Parliamentary Under-Secretary of State for Schools.

*Ms Bramman:* I am Julie Bramman, Head of Curriculum at DfES.

**Q2 Chairman:** Do you want to make opening statements, or shall we go into the questions?

*Jim Knight:* I hope we have supplied you with some reasonable written information.

**Q3 Chairman:** You have indeed.

*Jim Knight:* On that basis, it is probably a better use of all of our time if we go straight into questions.

**Q4 Chairman:** All right. Let me ask the first question. How did the Government formulate the ambitious and very precise targets for increasing the number of students taking physics, chemistry and mathematics A-level, as set out in “Science and Innovation Investment Framework 2004–14: Next Steps”, and what specific actions are you planning to ensure that these targets are met?

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*Lord Adonis:* My Lord Chairman, I cannot pretend that the precise targets are based on very advanced forecasting techniques given what has happened in the last few years. That would be too much to hope. What we have done, though, is to take a serious historical look at what has happened in entries for maths, physics, chemistry and biology at A-level and AS, looking at areas where there have been good things going on such as, for instance, additional entries in AS where there has been a good story to tell in the last two years, and looking at the historical decline over the last 12 years, to set a target over the next eight years to restore the position to broadly that which applied in the early to mid-1990s. Our view is that, given those are figures which were achieved by the system in terms of entries between 1990 and 1995 (the precise figure varies depending on which subject), with the additional measures we have put in place these ought to be attainable targets over the next eight years given, as I say, that in some areas progress has been encouraging. For instance, in AS entry, the first year of sixth form, there have been increases in maths and physics. We saw a notable increase in maths AS entries last year from 53,500 to 54,900, a significant increase in further maths AS, which is one of the fastest growing AS courses, and we also saw an increase last year alone in AS entries from 38,600 to just over 40,000. Alongside that, of course, we have got a number of initiatives in train, which you will want to ask more questions about, significant incentives on the recruitment of teachers. We are seeing a big increase in both the number and the quality of teachers being recruited in science in general and in scientific disciplines in particular. We have got a significant improvement in professional development for teachers with the National Centre for Excellence in the teaching of mathematics launched yesterday by the Secretary of State, as it happens. We have the National Science Learning Centre at York, which is now established, and a network of regional and local centres for continuous professional development both in maths and in science. So putting all of those together, we think that setting a target which seeks to restore us broadly in physics, chemistry and maths to the position that we actually attained in the early to mid-1990s is a realistic target to seek to achieve.

**Q5 Chairman:** You think it is realistic for physics as well, do you?

*Lord Adonis:* We think that is the most ambitious one by some way, but then of course that is also the one which has had the most precipitate decline, but we think it is an attainable target and there are some elements which are encouraging. As I say, when we look at the propensity of people to study physics A-level, if they have achieved highly in the Key Stage 3 test, the tests the 14-year-olds take, and if they have

the opportunity to go on and study three separate sciences at GCSE (which is something we have made much of in the Treasury document published alongside the last budget), in cases where students do attain high levels in the Key Stage 3 tests they then have the opportunity to take a separate physics GCSE and the propensity of them to go on to A-level is significantly enhanced. So again, if we can achieve the targets we have got for a bigger recruitment strand in physics teachers, a bigger take-up of the individual sciences at key stage 4, leading through to GCSE, then we have confidence that this will lead to increases in the numbers taking A-level physics. But I do accept that these are ambitious targets.

**Q6 Baroness Sharp of Guildford:** I have two questions. One is on mathematics. I have to confess I did not look up these figures, but am I right in thinking that in 1989 we had somewhere in the region of 80,000 young people taking mathematics A-level and that there was quite a dramatic drop between the end of the 1980s and the mid-1990s? I have got the figures here, but in your evidence.

*Lord Adonis:* The figures for maths A-level are in 1990 55,800; in 1997 56,600; in 2004 46,000.

**Q7 Baroness Sharp of Guildford:** I am obviously wrong there and I apologise for that.

*Lord Adonis:* But I do not disguise there has been a decline, but I am glad to say it has not been quite such a precipitous one.

**Q8 Baroness Sharp of Guildford:** On the question of taking three sciences at GCSE, have we got enough specialist teachers to be able to cope with the present demand for this?

*Lord Adonis:* Not at the moment, which is why we have been very careful in phrasing how we intend this development should be introduced. What we have said in the Treasury document is that we would expect comprehensive schools which have a science specialism—of which there are now 231, and there will be more this September—to be able to offer the individual sciences at GCSE level in addition to the substantial number of schools which already do, and we would expect them to be able to make that available not only to their own students but to other students in their localities where that is a practical proposition, and in some cases of course it will not be. Since those schools have already taken on a science specialism and therefore have additional resource and commitment in that area, we believe that is a practical proposition for them to do so, and of course they are reasonably evenly spread across the country too, so most large conurbations would have at least one of their secondary schools which has a science specialism either through the science specialist programme or because of other characteristics, for

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example most grammar schools offer the three sciences. So that would give us quite a large number of schools fairly evenly spread to offer the three sciences. Once we have reached that position, we believe it will then be possible to build out, provided we have the success that we are seeking in recruiting more physics teachers in particular, which is why achieving the target to move up to 25 per cent of the science teaching force having either a physics degree or being specially trained in physics—this could be biologists who take on additional training so that they can teach physics to a higher level—will be very important to be able to move out beyond the science specialist schools.

**Chairman:** Baroness Sharp, you had a question about encouragement.

**Q9 Baroness Sharp of Guildford:** Carrying on from this, do you think enough is being done to encourage able students to pursue sciences at A-level, in particular are students really being made aware of the very good career opportunities there are within the sciences? We visited a sixth form last week when we went up to York. We went to the new National Science Learning Centre. We also visited a school in York, and I think one of the issues which arose there was the degree to which there is, so to speak, conflict in students' minds between subjects such as psychology (which is a very popular subject) and other sciences at A-level. In terms of career opportunities, it seems that perhaps in relation to the opportunities which are available for those who are studying the hard sciences, chemistry and physics, they are perhaps not fully aware of all of this?

**Ms Bramman:** To be absolutely frank about it, everything depends on the quality and the inspiration of the teachers. In all my experience in this area, where you have talented and inspirational teachers they of course sell their subjects very strongly and all the opportunities which their subjects can bring. Where that is not the case, then students will tend to gravitate to subjects where they do have teachers who provide that stimulus. When we were doing the very detailed work for the Treasury reports we were very struck by the importance of pursuing individual sciences and high attainment at Key Stage 3 in their follow-through and the likelihood to go on to do physics at A-level and then at degree level, but actually thinking about it, it is no particular surprise that that should be the case, because for a school to be able to teach three individual sciences at GCSE it will have to have qualified teachers in all of those areas. You cannot teach GCSE physics without a physics teacher. That is a fairly big decisive first step in ensuring you have got teachers who are able to motivate their students, so when we saw the extraordinarily high correlation between high

attainment at GCSE, the likelihood to go on at A-level and the likelihood to go on at degree level, and having the individual sciences taught in a school, I think part of it is because the individual sciences probably do prepare you better and give you more depth in a subject. I think part of it also has to do with the fact that schools which can offer the three individual sciences are much more likely to have qualified and highly motivated teachers, particularly when it comes to physics and chemistry.

**Jim Knight:** I would only add to that three things. First of all, we think that it is more likely that if a school has a sixth form, you have that pull-through and that becomes easier, both for workforce reasons and for reasons related to the pupil's motivation. That is one of the reasons why we have this presumption for high-performing specialist schools to be able to start sixth forms, and we think that would be helpful in this regard, amongst other things. The second and third are both around perceptions of careers. One is the nature of the careers advice, and there is some evidence that people have this notion that science careers are being a scientist or being a doctor and they are not seeing the full range and excitement of things which you can then go on to do with science A-levels and science degrees. We are currently having some discussion around how we can develop information advice and guidance as part of the 14 to 19 changes which we are implementing over the next seven years or so. The third issue is the media perception.

**Q10 Baroness Platt of Writtle:** Just before you leave that, the original idea of Connexions was to help to be more inclusive for the under-developed part of the school curriculum for all the pupils. The careers advisers do need help to see where good careers can be developed with science qualifications. Is something being done about that in terms of continued professional development?

**Jim Knight:** Yes, there is a whole issue around continued professional development and that is something which largely lies with the school. It is the responsibility of the teachers themselves with the head teacher to work out what is the best CPD for the individual.

**Q11 Baroness Platt of Writtle:** I am talking about the careers advisers, who are very often coming in from outside, are they not?

**Jim Knight:** Yes. In respect of careers advice, one thing which I am very hopeful and optimistic about is the changes that we are bringing in in terms of the specialised diplomas, where we have 14 diplomas more or less designed by the Sector Skills Councils themselves, and there is the offer of A-levels and

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specialised diploma apprenticeships at 14. It is not going to be deliverable by any single institution. That then in turn creates more collaborative partnerships within the whole 14 to 19 educational environment and it embeds employers within that. Some of those—ICT, for example, is one of the first five that will be delivered from 2008—clearly have a science and a technology element within them and I hope that presence of the employer much more embedded within education, within 14 to 19, will assist the careers advisers because pupils will be able to see, work with and have work experience directly in work places where science is valued and science is talked about. The third issue was the media perception, and that is where it is clearly much more difficult for us from within Government to magic up some charismatic physicist whom everybody has heard of, who is presenting some marvellous programme which does for physics what Jamie Oliver does for school dinners, or what Tony Robinson does for archaeology, but clearly if that was to evolve, if we were to find through the media exciting ways of presenting physics and the excitement which it is possible to have around physics, then that would assist things considerably.

**Q12 Lord Howie of Troon:** Has this already been put to the Government? Do not the institutions of science have a great part to play in this? I notice, for example—I am a civil engineer, by the way—that architects have become very significant, whereas engineers have not, and that is largely down to the enthusiasm of the architects, or the profession, despite the Government. So you want to jazz them about a bit, do you?

*Jim Knight:* We do, and one of the other five specialised diplomas is engineering. I was talking recently to the person from industry who is leading for us, advising on the development of that curriculum, and we have got very good engagement from engineering employers and I hope that that coming together of education and industry in the case of engineering, as an example—

**Q13 Lord Howie of Troon:** I should just point out that the Royal Academy of Engineering is doing good work in this respect.

*Lord Adonis:* I should say, my Lord Chairman, we also work closely with the relevant professional bodies, too, for example with the Royal Society of Chemistry, which has put a lot of effort into the popularising of chemistry and the information about it in schools.

**Q14 Lord Howie of Troon:** That is my point, it has been up to them rather than you?

*Lord Adonis:* But we can do things together.

**Q15 Lord Howie of Troon:** Of course, I accept that. *Lord Adonis:* With the Royal Society of Chemistry, we have sent a copy of Bill Bryson's "A short History of Nearly Everything"—which some Members of the Committee may think is slightly dumbing down, but nonetheless it is a very, very good and exciting introduction for young people—to every school in the country. I did a launch at the Royal Society of Chemistry with the President of the Royal Society of Chemistry to get that going. There were very large numbers of pupils there and it has gone down extremely well in the schools, so I think there are things we can do in partnership with the professional bodies.

**Q16 Lord Taverne:** Do you also have contact with the television companies, schools programmes? There are some very, very good science presenters about who could stimulate a great deal of interest and there is nothing like television to be the media to use it. One gets the impression that some of the BBC science programmes dumb down an awful lot and can be very boring and very slow, but it is something where I should have thought the Government could be in constant touch.

*Jim Knight:* Yes. We have a very direct relationship as a department with the BBC and certainly it is something we need to exploit, but I do not know that Government ministers or even their officials are the best people to come up with the innovative, exciting programme ideas which will really turn on the nation.

**Q17 Lord Taverne:** No, but you could ask them what they are doing.

*Jim Knight:* Yes.

**Q18 Chairman:** I think there is another point that I would like to hear your opinion on here which is not specifically amongst the questions which we have drafted, but it is a question of when we expect students to specialise and how specialised they become. I have always been concerned that a lot of our very bright students are encouraged to be too narrow too young. A lot of the top engineering schools, for example (declaring my interest as an engineer and former head of the Engineering Department in Cambridge), require students just to do mathematics and physics and are happy for them to have only done those subjects from the age of 14. I do not think that is in the students' long-term interests and I do not think it is in the country's long-term interests, and yet a lot of the forces are pushing things that way. I am somewhat worried that the Government, in its attempt to increase the numbers in mathematics and physics, may in effect attempt to hot-house these students and produce very narrow

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students who can pass these A-levels, but that is not going to serve those students well in the long run.

*Lord Adonis:* I can completely understand that concern, my Lord Chairman, and of course there is a wider debate about whether in this country we specialise too soon compared with other countries which have baccalaureate-type systems of examination and assessment. However, I think the situation has improved markedly since the mid-1980s in two respects. The first is that we now have a National Curriculum and a requirement to continue a broad and balanced curriculum up to the age of 16, which did not apply before. There was not a National Curriculum before with the requirement to study the set range of subjects. I think that has improved matters. The second is the introduction of the AS exam, which whilst it has not had the full broadening effect which many had hoped, it does mean that most students do one, and in some cases two more subjects for at least the first year of the sixth form than they did before. Typically, an able student heading towards university would now do four or five AS, narrowing down to three A2. That is an improvement in terms of the range of subjects on what applied before, where they would traditionally just do their three A-levels. So I think we are moving in the right direction, but of course there is a wider debate about whether one should have some form of baccalaureate which would actually oblige students to keep a wider range of subjects going right the way through to 18. Universities, in my experience, are not wholly in support of that. They quite like having students who come through having developed depth in their subjects in the sixth form and I do not think we would have an entirely straightforward relationship with, for example, your own Alma Mater if we were to suggest that they were not able to study three subjects in great depth in the sixth form.

**Chairman:** My personal feeling is that the universities are in error in holding to what I see as an old-fashioned way of looking at education and I think we are almost alone in Britain in not requiring, for example, students to carry through English until they go to university, regardless of what subject they are taking, and on the other hand, on the art of numeracy, that mathematics would be something which is good to carry through in some form.

**Q19 Lord Howie of Troon:** The Lord Chairman, I think, is talking about the like of the Scottish Higher Leaving Certificate, which is a kind of lesser baccalaureate.

*Lord Adonis:* It is, though of course students study it for one year less.

**Q20 Lord Patel:** We have been informed that there is a serious imbalance between the number of boys and girls studying physics at A-level. Further evidence

has been presented which suggests that there is also an under-representation of certain ethnic minorities at GCSE level and beyond in physics and chemistry. What impact is this likely to have on such things as the recruitment of teachers for physics, and also what is being done to address those issues?

*Lord Adonis:* Shall I start on this issue? There is, of course, a big historic issue about girls studying physics. The data are quite compelling. In fact people say, rather glibly sometimes, that biology is sort of sweeping all before it in the competition between the sciences for people studying A-level. In fact, actually there are more boys studying physics than studying biology at the moment. Last year there were 18,900 entries for physics A-level amongst boys as against 18,600 entries by boys for biology. However, amongst girls the picture is starkly the other way; it is 27,000 girls entered for biology A-level against 5,000 for physics A-level, and indeed if we could increase the number of girls studying physics that alone would actually bring the numbers in line with biology. I think the long historic reasons why physics is seen as an attractive career and subject for boys we are not going to turn around immediately, but we are seeking to do a good deal in promoting professional development for teachers, and of course promoting more and better teachers in this area who will make the subject more exciting. The science learning centres which we have established, the National Science Learning Centre in York and the nine regional science learning centres, are helping to set up courses specifically to help physics teachers improve the quality of their teaching and inspire their pupils. They are also at the moment engaged in an action research project with the Institute of Physics specifically looking at the international evidence of the teaching of physics to girls. We are awaiting that report—I am told it will come soon—to look to see whether there are specific continuous professional development initiatives we should take which would promote better teaching of physics to girls.

*Jim Knight:* In terms of ethnicity, the statistics we have show that pupils of Chinese and Indian ethnic origin are the highest attainers, both at GCSE and at A-level, but equally people of black ethnic origin are lower attainers generally. It is a mixed picture and, I am sure, reflects all manner of different issues, but these are difficult nuts to crack, I think particularly in respect of girls and how we interest more girls in physics, any advice we can get from the Committee on how we deal with that would be warmly welcomed!

**Lord Taverne:** We have had a certain amount of evidence which has remarked on the paucity of data about teacher supply and demand. What plans are there to develop a more effective and systematic approach to data collection?

**Chairman:** I am afraid we will have to adjourn because there is a division.



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*The Committee suspended from 4.11 pm to 4.19 pm for a division in the House*

**Chairman:** Do you want us to repeat the question?

**Q21 Lord Taverne:** It is clear, I hope.

*Jim Knight:* Yes. Currently, in essence we know on an annual basis the vacancies and we know those coming into the profession, and we published this year a report done by the NFER (the National Foundation for Educational Research) on the detail of the teaching workforce in respect of maths and science teacher deployment. So we have a figure right now which says how many there are and we are also able to see who is coming in and who is going out. At the moment, that is as good as we have got, but we recognise that we could and should do better in order to be able to fulfil the aspirations we have got to improve the recruitment and retention of teachers in science. Therefore, from 2008–09 we will require every school through IT to be able to submit returns to us on an annual basis right down to individual teacher level so that we can monitor on an annual basis what the movement is and what the trends are, which will enable us to monitor more carefully our progress towards achieving the quite ambitious targets we have set for ourselves in respect of teacher recruitment and retention.

**Q22 Lord Howie of Troon:** Going on from there, you have told us you have got certain information about who is coming in and who is going out, but what I would like to know is how great is the shortage of specialist science teachers?

*Jim Knight:* Our data from that study from NFER, which I have just referred to, show that in respect of the teaching workforce with a specialism—and as Andrew said earlier on, it is teachers with a specialism who really make a difference in teaching terms—in physics it is at 19 per cent, chemistry at 25 per cent, and biology a massive 44 per cent. Ideally, we would have that evenly balanced because we do not differentiate between the three core science subjects and we would want to see them each taught equally well with that balance of  $33\frac{1}{3}$  per cent each. However, when we have put together our targets in respect of addressing this, we have also had to look at what we think is realistic and achievable for us, as in the design of any good target I would hazard to say, and that is why we have come up with targets of 31 per cent for chemistry and 25 per cent for physics, which is essentially looking for an uplift of six per cent on each of those two target subjects.

**Q23 Lord Howie of Troon:** I am always very uneasy about targets, because you either make a target which you can reach, which is a nice thing to do, or you make a target which is an aspiration and you cannot reach it, and disappointment happens, but in the face

of the shortfall which you gave me how do you expect to deliver the entitlement from 2008 for all pupils achieving at least level 6 at Key Stage 3 to study three separate science GCSEs? Is that a real hope or is it, shall I say, rhetoric?

*Jim Knight:* We have got a series of actions which we are taking. Some have been built into the assumptions around the targets and some are actions in order to allow us to deliver our targets, so we are improving the bursaries which are available. Obviously you are aware of the Government's golden hello of £5,000. We are increasing from £7,000 to £9,000 the bursaries which are available to new recruits to offset fees, and so on. We are looking forward to, we hope, again from retraining teachers, returning teachers from other subjects as a result of falling pupil rates and the use of subject enhancement courses prior to initial teacher training, and we are increasing flexibilities for teachers to work longer with the new teachers' pension scheme, which Andrew jointly helped to negotiate. Then on the actions to achieve the targets, we announced in the budget document additional courses to enhance physics, chemistry and mathematics subject skills for those entering teaching who do not have a recent degree in the subject, expansion of the Student Associate Scheme, which encourages undergraduates to go into teaching, and then the development of a new diploma course to train teachers to be physics or chemistry specialist teachers, and finally further incentives for teacher training providers to find physics and chemistry training. I think they get a £1,000 incentive at the moment and we are looking at how we develop that.

**Q24 Lord Howie of Troon:** 2008 is quite soon. I hope you mean the end of 2008 and not the beginning of it. Is this not somewhat fanciful?

*Ms Bramman:* I think we are also building on the collaborative arrangements which Andrew spoke about earlier and using specialist schools to share out their expertise more widely, so I think it would be wrong to look at these different developments in silos. We are hoping that the sum of all of those different initiatives will mean that we can actually reach out to pupils in all schools to enable this to happen.

**Q25 Lord Howie of Troon:** I notice you said "hoping", which is probably the correct word.

*Lord Adonis:* If I can put it in context, 52 per cent of comprehensives which have a science specialism at the moment already offer the three individual sciences and 20 per cent of the other comprehensive schools offer the three individual sciences. So we are not starting, as it were, with a desert, we are starting with a significant body of schools which already offer those. As I said to Lady Sharp earlier, the emphasis

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over the next year is to see that all of those specialist schools, which are fairly evenly spread across the country, are in a position to be able to offer all three of the individual sciences. We believe that is an absolutely realistic and attainable target. We have spoken to the organisation which works with the Specialist Schools and Academies Trust and they believe this can be done, so we believe that we will have a reasonably even spread of schools in most localities where there is at least one school which offers the three individual sciences and therefore, of course, has teachers who are qualified in all three. The question then is at the beginning, because, as you say, 2008 is only two years away, is where the collaborative arrangements—which need not mean students moving from school to school (which can only be done to a limited extent), but it could mean the sharing of teachers between schools, where, for example, a school which does not have a physics teacher, making a physics teacher available for part of the week so that they can offer the GCSE provision in a specific subject—we believe that those sorts of collaborative arrangements will enable us to spread out from this large core of schools which are already offering three individual sciences to the system more widely. But I do accept that it is a challenging target which we have set.

**Q26 Lord Howie of Troon:** Quite! You are offering something to all pupils and you have got a really substantial shortfall. If I were to say that I am not convinced, I hope I do not hurt your feelings.

*Lord Adonis:* I would say we have a lot of work to do, I completely accept that.

**Q27 Lord Howie of Troon:** You are telling me! One last question: when we were up in York last week I was quite interested to find there was a course which we went to see of teachers going back to York for further study and I was impressed by the number of students there who were people who had come into teaching after another career. I am wondering how much you are doing to encourage that kind of thing? I think it is quite important in the scientific field.

*Jim Knight:* It is, and there is some quite significant work being done on that. The employment-based routes are expanding. We have developed the conventional ITT (Initial Teacher Training) places, but the employment-based routes are expanding well and in London the Teacher First is also operating well, which I think is addressing the question you are asking and we have got a good story to tell.

**Q28 Lord Howie of Troon:** Good. Can I give you a sceptical figure?

*Jim Knight:* You can. I am used to sceptical figures!

*Lord Adonis:* There is one very arresting statistic in this area, though. The average age of new teachers coming into the state system is now 30, thanks to the really big increase which has taken place and the number coming in as career switchers in their thirties and forties, many of whom bring, of course, a great experience of careers in these areas, coming back to Lady Sharp's question about how you engage people with a sense of excitement and employment opportunities. Having people who have been in these jobs before who come into the profession with that experience will help a lot. That is a transformation on the position even 10 years ago, let alone 20 or 30, when virtually all teachers went in doing their PGCE after university and then became lifetime teachers. So I think we have got a good story to tell there, and the development of what are called employment-based routes, which is the capacity to train on the job as a career switcher with a salary, which is vital of course for career switchers who have families, that barely existed 10 years ago. Now, as Jim said, there are 750 who went through the employment-based route in the sciences and maths out of 3,600 last year, so it is a significant proportion that are now coming in as career switchers.

*Jim Knight:* There are some Higher Level Teaching Assistants as well, which is something we are particularly developing with maths and science. That is another option which some career switchers are opting for as well.

**Lord Howie of Troon:** Good. Thank you.

**Q29 Baroness Sharp of Guildford:** I think one of the things which came through from our visit to the centre in York was the size of classes in teaching in science and that in particular some of the older laboratories were built to handle 24 and they are trying to cope with 32, and that is very difficult, but also that for the Key Stage 3 classes the excitement comes from the practical hands-on part and it is actually extremely difficult to handle classes of over 30 when you are doing practical work with youngsters between 11 and 14. I wondered what projections you were making, in the light of your target, about class sizes in the future in these areas?

*Lord Adonis:* The average class size as of last year at Key Stage 3 is 25, at Key Stage 4 it is 22, and at Key Stage 5 (that is post-16 students on AS and A-level courses, in what we used to think as the lower sixth year) it is 12.5 and in year 13 it is 9.2. So most classes where you need the specialist science teaching would be substantially under 30, but the design of what we call the department the classroom of the future, with the modern science labs and all that, they would be able to cater for 30 plus, but of course I completely accept that too many of our schools have very outdated and antiquated teaching facilities and they

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often do not have the facilities which enable them to take large classes in these subjects at the moment, but we are seeking to build schools for the future.

**Q30 Baroness Sharp of Guildford:** Obviously where you have got a popular school which has got, so to speak, the full numbers you are unlikely to hit the Key Stage 3 classes of 30?

*Jim Knight:* Yes, and obviously we all know about the demographic trend downwards. Also, these percentages mean that we are looking for larger numbers of teachers, so fewer pupils and more teachers suggests that things might move in the right direction in terms of class sizes.

**Baroness Sharp of Guildford:** It depends upon whether there are also more resources!

**Q31 Baroness Platt of Writtle:** Around 40 per cent of new teachers leave the profession within five years. What are you doing to improve retention rates among science teachers in particular?

*Jim Knight:* The first thing I would say is that we do not have a particular problem with science teachers that is any different to other teachers.

**Q32 Baroness Platt of Writtle:** Surely it is worse?

*Jim Knight:* No, the overall picture is around the same, and there is no particular problem with teaching that is any different to most normal careers with about nine per cent leaving. Ten per cent, I think, is the average across industry. So I would not want people to think that there is a particular acute problem, but clearly given all of the issues we have just been talking about, if we can retain staff better and recruit them then we are going to address the problems we are all concerned about more easily. So there is a wider picture there, but I take the question very seriously. We have introduced changes to the way teachers are paid. We have increased the main pay scale and we have created an upper pay scale, and these changes have accelerated teachers' careers and allowed teachers to obtain significantly higher salaries. It is now possible, I think, to earn up to about £50,000 as a teacher, but the vast majority of teachers are not motivated by more pay. That is not why they came into the profession. Male teachers are slightly more motivated by pay than female teachers, I am told, but nevertheless I think the figure is around 78 per cent of teachers are motivated by the desire to teach children, to be part of children's learning and it is not about pay at all. A work/life balance is important for them and, as you know, we have introduced a new workforce agreement so that all teachers now have 10 per cent of their timetable for PPA (preparation, planning and assessment). I think that given the motivation for people to go into teaching being around their desire to work with children and to help children to learn, we have got to

make sure that children are doing better, and we have discussed some of that. That will increase the job satisfaction of teachers and make them want to stay, doing the job they are doing. We have also got to make the experience of being in the classroom more pleasurable for them, and that is where the work we are doing on behaviour comes in. There is a whole range of issues we are tackling on behaviour management in terms of teacher training and ITT, and so on. There are standards and requirements to help ensure that training tackles issues such as behaviour management. The performance management for teachers means that teachers will be reviewed regularly against the standards for classroom teachers and senior teachers will be expected to contribute to the climate of good development, for example by coaching or mentoring others on behaviour. In the Education Bill, which your Lordships are currently debating, there are important measures to help teachers to give them powers to discipline, for example, to help schools work with parents through parents' contracts and parents' orders, which I think will also be helpful in terms of behaviour. Against an overall background where Ofsted report that 93 per cent of secondary schools have satisfactory behaviour and 99 per cent of primary schools do, I still think it is an area where we can do better, particularly with the low level disruption in the classroom. It is an area I am particularly interested in and it is one which the teaching unions talk to us on a regular basis about, and of course it is one which parents are concerned about. I think as we develop our policies, subject to your Lordships and our House, once we get the powers in the Bill then again I think we can make further improvements which will make teaching more pleasurable and which will allow teachers to get on with teaching more rather than just minding the children.

**Q33 Baroness Platt of Writtle:** You have only got to have two disruptive boys and nobody else is learning really, are they? I know about golden hellos, but you said that they were offered higher salaries. What did you mean by that? Does that go on through their career?

*Jim Knight:* You cannot offer a higher salary just by subject.

**Q34 Baroness Platt of Writtle:** I understood that was what you were saying?

*Jim Knight:* No, the creation of the upper pay scale is something which is for the individual and it is up to individual schools and head teachers to work this one through. There is the potential for a higher pay scale for all teachers.

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**Q35 Baroness Platt of Writtle:** For what reason?

*Jim Knight:* That depends upon the responsibilities they are taking on and the quality of their teaching.

**Q36 Baroness Platt of Writtle:** Thank you. On this question of encouraging returners, how are you thinking? I am a Patron of the WISE campaign, Women into Science, Engineering and Construction. This is something we have gone into in some depth. There is a fertile field of married women returners, who have been doing other jobs—that was Lady Sharp's question earlier—where their children are beginning to grow up. Teaching then, with a child at school, is a very attractive proposition, but they will probably need continuing professional development to bring them into the teaching skills. Are you doing anything about that?

*Ms Bramman:* You have probably seen the TDA, the media advertising campaigns, which are on posters and on our televisions as well, which have been very much focused on mathematics and science generally to try to encourage more recruits to that. We also have the new science and mathematics higher level teaching assistants, which we think will be particularly attractive to returning mothers in that you can come into a school as a higher level teaching assistant—

**Q37 Baroness Platt of Writtle:** If they get some opportunity for refreshment so that they can feel capable.

*Ms Bramman:* That is right, so they need the training we are offering now for the higher level teaching assistant. We are also then looking at progression routes where people can move from that status to full teaching status, quite possibly through the employment-based routes which Jim mentioned earlier, so that you could actually stay in a school and progress from being a teaching assistant up through to being a fully qualified teacher, and along with the subject enhancement courses we spoke about, where people can update their subject knowledge from where they had been some time ago, I think we do have in place all of the rungs now to allow that to happen.

*Jim Knight:* In my own constituency I know of a number of individuals whose children have started school and they are wanting to return to work, and working in school, as you say, is very attractive to them. They are not previously qualified teachers, but they have come in perhaps initially just to volunteer. They might have relatively low self-esteem—

**Q38 Baroness Platt of Writtle:** I am thinking in particular of women who have scientific skills but they need updating.

*Jim Knight:* The HLT (Higher Level Teaching) system is a very good one to give them the confidence and then get them back into teaching, but there are also others who are progressing through. They start as volunteers, they become teaching assistants, they then become interested in teaching as a career and then effectively learn on the job and work their way up through. I know of one or two individuals, as I say, in my constituency who are then doing Open University degrees and then taking teaching qualifications to become teachers.

**Q39 Baroness Platt of Writtle:** I am particularly talking about people with experience, because if you have had experience you can make teaching much more interesting and fun, and if it is boring that actually puts young people off.

*Jim Knight:* Absolutely, yes.

**Q40 Chairman:** Could we just pursue that a little bit more in terms of market forces. Is there a policy or are you entertaining a policy of actually paying science teachers more than other teachers?

*Jim Knight:* We would be constrained, I think, by the ability to say across the piece you should pay maths, physics and chemistry teachers more. There would be a huge deadweight cost attached to that and I do not think that would be appropriate, but we need to be able to offer some flexibility to governors and head teachers if they have particular problems to be able to work something out locally.

*Ms Bramman:* We have said that we will ask the School Teachers' Review Body for their advice on how schools can use the flexibilities they already have to award additional pay to their teaching staff to support the need for more maths and science teachers. We are also asking them for advice on whether we would need to incentivise existing teachers to take the new diploma we are suggesting should be there through CPD so that people who are currently teaching biology deepen their subject knowledge in physics and chemistry to meet our overall proportion targets.

**Chairman:** Good. Thank you for that.

**Q41 Lord Howie of Troon:** Is your main constraint the teachers' unions?

*Jim Knight:* As I say, there are constraints around the deadweight cost of doing this and, as I said earlier, the vast majority of people do not go into teaching for the money and I think it would be a mistake for us to think that if we threw lots of money at the problem that would resolve it. I do not think that would be the case.

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**Q42 Lord Howie of Troon:** That is not really what I asked. I asked, was the major restraint the teachers' unions, who sometimes find it difficult to come to agreement?

*Ms Bramman:* I think the major restraint is the advice we have had from the School Teachers' Review Body in the past, where we have asked these questions and they have come back to us as a department and said there is insufficient evidence to suggest that this would be a sensible thing to do.

*Jim Knight:* As a department we have a very effective social partnership. We have a workforce agreement monitoring group, which meets on a regular basis, and I have been to one meeting in my limited career as the schools minister but I have committed to them to meet with them on average every other meeting, and they meet, I think, every six weeks. I would regard the teaching unions generally as being very positive, very helpful to us. We cannot deliver on our reforms, we cannot deliver on our educational aspirations for our children without the workforce working with us and we have to value them. Yes, we have our differences with some of the unions, but in general terms the partnership is something we value hugely in the department.

**Lord Howie of Troon:** Having been a trade unionist for 50 years, I take that as a yes!

**Q43 Lord Paul:** A pledge was made in the Science and Innovation Investment Framework to develop an accredited diploma to give existing teachers without a physics or chemistry specialism the necessary knowledge to teach those subjects effectively. Can you tell us what progress has been made on that?

*Lord Adonis:* We only announced this in the budget, so progress at the moment is at a very early stage where the preliminary meetings have been held. The Training and Development Agency for Schools, which is the body which is responsible for teacher education and training, is taking this work forward with us and we are in discussions with the science learning centres, including the National Science Learning Centre, as to how we take it forward, but I will not pretend that this work is developed at the moment. We only announced it in the budget and it is going to take some time before we get the properly accredited diplomas in place.

**Q44 Lord Paul:** Is there any framework or a time period for the planning?

*Lord Adonis:* I would hope we would have something very positive to show this time next year in terms of a worked up qualification which we can start taking forward, but it is going to take some time, obviously, because we are doing this from scratch at the moment.

**Q45 Lord Paul:** Will the teachers be expected to study for their diploma during school hours or in their own time? If the latter, what kinds of incentives could be provided to make the course an attractive option?

*Lord Adonis:* I expect it will be a mixture of the two, as it almost invariably is with teachers' professional development. As Jim said, there are now planning and preparation times. There is more time built into the school week for teachers to engage in their own professional development, but equally teachers do willingly give of their time outside the school day and year to update their skills, so I expect it will be both. One of the biggest incentives we can provide is similar to the incentives we provided in the courses and science learning centres, which are bursaries and discounted costs for the courses so that teachers do not have to bear those costs themselves, and if they see promotion and job opportunities for themselves by this route I think they will find that quite attractive. In my experience, physics teachers are at a great premium in terms of job opportunities at the moment, so biologists who use this diploma to get a good physics qualification as well I think will find this significantly improves their employability in the professions. I think that will be a very attractive feature in taking these courses.

**Q46 Lord Paul:** We were very impressed with the learning centre in York.

*Lord Adonis:* I am glad, because we spent a very great deal of money on it! I should add, with the Wellcome Foundation as well.

*Jim Knight:* It is a £51 million project and we contributed £26 million of that, just over half.

**Q47 Chairman:** We were very impressed with it, but we were also aware that it was under-utilised at this stage and we hope that the utilisation will rapidly reach 100 per cent.

*Jim Knight:* Absolutely.

**Lord Howie of Troon:** It was also going to run out of money fairly soon.

**Q48 Lord Taverne:** I want to ask about continuing professional development. We had some evidence from the science learning centres that a recent survey of teachers found that half of all secondary science teachers in the survey said they had not had specific CPD (continued professional development) in the last five years and they listed the barriers to it: cost, the difficulties with the school getting specialist supply cover, and also the policy in some schools of discouraging external CPD in favour of in-house provision, which they then say is not desirable or not the best because schools lack subject-specific expertise in physics, and if they do they are not in a position to provide training at the subject in-house

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and there is an increasing tendency to deliver CPD in that way. They also mention the absence in some schools of the policy of entitlement to CPD. How is the Government addressing these barriers?

*Jim Knight:* We do think CPD is very important. We also believe that we should trust schools. Back in 2004 the funding for CPD was delegated down to schools for them to make their own decisions about how they should spend it. As I said before in answer to Lady Sharp, I think it was, it is up to the individual teacher and their management, ultimately the head teacher, to decide on the CPD needs of the individual and of the school, but the science learning centre we were just talking about, their courses are subsidised to provide free or reduced cost courses and the secondary national strategy pays for cover for attendance at regional conferences as well. So we are trying to give as much encouragement as we can for the use of CPD outside of the school. We talked a little bit earlier on about the collaboration and the specialist colleges. I think there is a role for them also in terms of CPD to deal with some of the absence of expertise, particularly in physics, which you talked about, Lord Taverner. It is a difficult balance, I think, that we are trying to strike between not dictating what should happen and enabling it to happen. As you saw at the learning centre, I think we have made some advances on that, but perhaps this is where we need to go.

*Ms Bramman:* On the demand side, the Training and Development Agency for Schools is currently looking at new standards for teachers and that will include standards about keeping your subject knowledge up to date and showing that you are taking CPD seriously, and that will be something which is looked at in the new performance management systems which schools will be putting in place for individual teachers. So I think we are raising the profile through that course as well as for the investment.

**Q49 Lord Taverner:** But if there is a trend towards greater in-house provision of these courses, it is unsatisfactory when something is going wrong. Is it in fact still the trend and are there not some ways in which you can reverse it?

*Ms Bramman:* There is a trend towards in-school provision and a lot of the time that is a very efficient way to do things, particularly where the issues are not perhaps completely subject-specific but are about raising attainment in minority ethnic groups, or for boys, where you might have a whole school or departmental session which is CPD. Sometimes it is recognising whether what you are doing is CPD. It is costly to take teachers out of school and we should not be blind to that. It also means that a class does not have its teacher for the time that teachers are out of school. So we do need to think innovatively how

we bring CPD into schools as well as providing these good quality opportunities, particularly in science, where the subject knowledge needs to be kept cutting-edge.

*Jim Knight:* With the work at regional science centres, for the first two years of operation we have provided funding so that teachers can go and access those. So we accept the seriousness of the challenge and we hope that by teachers getting the experience and schools having the experience because we have funded that travel, and the ability of teachers to be able to go to that network of learning centres, that they will then continue to value it after those two years.

*Lord Adonis:* We are also boosting a similar sort of provision for mathematics as well. We have got not only the national centre for excellence in mathematics but we have also got the 47 further mathematics regional centres, that is one for every Learning and Skills Council area. They do provide courses directly for students to particularly encourage the take-up of further maths. I think the development of these centres is part of the reason why we have had a big increase in numbers taking further maths at AS, but they also do have a CPD role in respect of teachers and I think that will have an impact as well.

**Q50 Lord Howie of Troon:** My Lord Chairman, when I was a functioning civil engineer many years ago we did not have CPD. However, if you failed to keep up with your subject you were in danger of losing your job, and this was something of an incentive. Is there not some danger of you over-structuring professional development here?

*Jim Knight:* As I said, I think it is something which is down to the individual teacher and his school, so we are not being as prescriptive as perhaps some people would argue.

**Q51 Baroness Sharp of Guildford:** I wonder whether in terms of creating incentives you had thought of linking up with the universities and perhaps the OU so that teachers who do a bulk of CPD can get credit for it and then, as with the Open University, accumulate these credits towards a post-graduate qualification? If you think of the accountants who do MBAs, and so forth, very much in their spare time, one of the things which I think struck us about the York centre was that on the whole the teachers do not want to give up their own time. They will come in school time but they will not come in holiday time. If there is some incentive that you are actually going to get something from this, then there is a greater incentive. You might get some credits from going on CPD where the school paid, but then you get some credits from giving up some of your own time, and of course you could do it via distance learning as well.



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*Ms Bramman:* The Open University does run some courses where you can get accreditation like that, which are funded by the Training and Development Agency for Schools, but it is a very interesting idea on how we might unitise CPD. We are definitely convinced that with the new diploma we are talking about that needs to be accredited and very visible.

*Lord Adonis:* I think those are important and it is worth us looking further at what incentives we might give. I would just add two other points to this, which is that for teachers to go into what is called the upper pay spine and to qualify for the new excellent teacher grade which is being introduced, they do need to be able to demonstrate excellence in their own subject area as well. That is a requirement which will be there in the new teacher standards which the Teacher Development and Training Agency is working on at the moment. I think that will be quite a big incentive for teachers as they see the prospect of higher grades and higher salaries, for which one component is good up to date knowledge and excellence in their subject. I think that will be an incentive for them.

**Q52 Chairman:** The National Science Learning Centre funding is time-limited, is it not, and at the moment the fees are being covered by bursaries? How do you envisage the future? Is that centre going to be able to survive in a fully populated manner when that funding falls away?

*Ms Bramman:* The National and Regional Science Learning Centres are in slightly different positions. The National Science Learning Centre is funded by the Wellcome Trust and the commitment there from Wellcome, providing it is effective, is to continue funding it up until 2013. The Regional Science Learning Centres are funded for this spending review period. We will have to look through the comprehensive spending review in making a bid alongside all of the other priorities which the department has.

*Jim Knight:* It is certainly above the pay grade of any of the three of us to anticipate the outcome of the spending review, I am afraid.

**Q53 Baroness Sharp of Guildford:** Are you sure that the Wellcome bursaries are funded to 2013?

*Ms Bramman:* I am not sure how long the centres are funded for, but there is a break off point where a decision is made to continue it.

*Lord Adonis:* It goes without saying, my Lord Chairman, that we have not just set up these nine centres and a national centre to see them empty in a few years' time, so we will be monitoring the situation very carefully, and although it is well above our pay grade, we will see what will happen in the next spending review! There are large budgets in the Department for Education and Skills and I am sure

there will continue to be large budgets, so the key priorities will remain key priorities.

**Q54 Lord Howie of Troon:** When does the next review happen?

*Lord Adonis:* Over the next year, the spending review.

**Q55 Baroness Platt of Writtle:** I think perhaps to a certain extent my question has been answered. You mentioned the Wellcome Trust. What about the Salters' Company, because they do a lot for science, do they not?

*Ms Bramman:* There are lots of organisations which are doing a lot in science.

**Q56 Baroness Platt of Writtle:** Do you work with them?

*Ms Bramman:* I think we are getting a lot better at coordinating what is actually happening out there so that people are working towards the same priorities. Obviously organisations which are independent of government are entitled to spend their funding and their charitable trusts in the way their trustees think fit, but I think that we are getting better at getting the strategy right and the School Science Board which we have recently set up has a number of external organisations sitting on it so that we can make sure that we do continue to get better at that coordination. Some other examples, specific examples we are doing at the moment, because we have spoken about the science learning centres and about the maths centres, we are going to pilot co-locating some of the regional maths coordinators actually into the Regional Science Learning Centres to see how that runs. The Science Learning Centres are already delivering CPD for teachers and lecturers in FE as well as schools, so we are starting to join those up and making things more coherent, but we think we do have still quite a long way to go on that.

**Chairman:** Let us move on. Lord Howie, please.

**Lord Howie of Troon:** As you know, we went up to York last week and we went to one particular school where we spoke to the science teachers and they were all—I am not saying harassed, but I was going to ask you about changes in curriculum which are coming up.

*The Committee suspended from 5.01 pm to 5.10 pm for a division in the House*

**Chairman:** I think we will jump Lord Howie's question and come back to it.

**Q57 Baroness Sharp of Guildford:** How far is the Government addressing the relatively poor conditions in laboratories? We touched upon this earlier, in the light of the local authorities' finding in the survey which they undertook that 41 per cent are basic or uninspiring and a further 25 per cent of

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laboratories were downright unsafe. Are you confident that the necessary improvements and rebuilds will take place? As a supplementary to that, what priority does renewing laboratories have within Building Schools for the Future?

*Jim Knight:* We do put a priority on this. We think it is important and I am confident that we will get the exciting and inspirational labs which we need in the future. Building Schools for the Future is obviously a very exciting programme, to replace or refurbish all secondary schools by 2020.

**Q58 Baroness Sharp of Guildford:** Golly!

*Jim Knight:* Yes, “golly”! I never knew spending so much money could be so painful, but we have shifted from what was, I think 10 years ago, a capital spend for schools of £0.6 billion. We are currently spending £6 billion, it has increased ten-fold, and Building Schools for the Future accounts for about half of that money we are spending. To ensure that the school science labs are the labs for the future, we have a programme called exactly that, School Labs of the Future, and that project is bringing together leading designers with experts in the fields of science teaching and learning together with schools to how we can develop exemplar designs for science laboratories which can then be used and built into the BSF programme. I am the department’s design champion for my sins and it is something I am looking at pretty closely, and I want to make sure that through these demonstration projects we have got these inspirational laboratories that we need, not just functional and fit for purpose, they are doing better than that, as inspirational learning environments.

**Baroness Sharp of Guildford:** Certainly the laboratory we saw at the National Centre was interesting both in design and, as you say, inspirational in what can be achieved within it.

**Chairman:** Lord Howie, can we have your question again, please?

**Q59 Lord Howie of Troon:** Thank you. Before I do, could I say that as the design champion, do you work with CABE?

*Jim Knight:* Yes, they have been in to see me and I had a very interesting meeting with John Sorrell and also here at the House I took part in a meeting and a reception he held to celebrate something the Sorrell Foundation had done in terms of involving pupils, effectively in putting the design brief together. Even in some of the capital projects which have very recently been opened there is some good design but also some pretty poor design and it is something we have to continue to work hard at, letting light and space into buildings, because that is at the heart of making them the sort of learning environments which we need.

**Q60 Lord Howie of Troon:** I know CABE pretty well, and I must say you sound like a serious champion, which is good to see. There is a compliment for you!

*Jim Knight:* Thank you. I will add that to balance off the scepticism we had earlier!

**Q61 Lord Howie of Troon:** What I was asking about was the upcoming changes in the GCSEs, which I think come up in September, which is quite soon, and some of the teachers whom we saw in York, though they seemed themselves quite ready, did think it was a very short time for teachers to get ready for the new changes and that it actually put a considerable burden on them where they were getting ready with the plans while at the same time carrying through their ordinary duties in these present months. Have you given them enough time?

*Lord Adonis:* We do not minimise the extent of the changes, but there has been a lot of activity with the schools. I think the teachers you saw did feel well prepared, did they not?

**Q62 Lord Howie of Troon:** Yes, they were.

*Lord Adonis:* Which is encouraging. The national strategies, which are the field force which the department has for each of the main subject areas with the professional staff who actually work with the local authorities and schools to see that training is taking place, they have been on the case for a good while now working with the schools, with the subject associations and the local authorities to see that these changes are properly implemented, and the feedback we are getting is strongly encouraging. So we do recognise that it is a substantial change, but the information we are getting back is that the schools will be well prepared when they start in September.

**Q63 Lord Howie of Troon:** I thought for a minute you were going to say it was a challenge.

*Lord Adonis:* All these things are challenges!

**Lord Howie of Troon:** Thank you very much.

**Q64 Chairman:** Let me ask what may be the final question, although I think Lord Taverne has another question. We have been told that there are insufficient numbers of science technicians, that they are poorly paid and that there is no proper career structure. What can be done to improve the working conditions of science technicians and to recruit more of them? I must say that the technicians that we met in York were enthusiastic but they did seem overloaded, and they also did not feel that they had a real career progression in front of them.

*Jim Knight:* I think they do perform a really important role. The survey I referred to earlier, the research by NFER on the workforce, showed that 83 per cent of science departments had at least

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one technician, but that they were rarely or never involved with working with pupils to support learning in class. I think there is potential for them to do more and develop careers, and the higher level teaching assistant route is one which I think can offer that. I think it is important that we are offering them CPD now through the Science Learning Centres and I am glad you were able to meet some while you were there, but the substantive question about recruiting more and offering better routes through is the subject of some work we are doing through the Workforce Agreement Monitoring Group which I referred to earlier. I have currently been considering some interim work which WAMG (as we call it) has done on support staff in general, where we are engaged very effectively with the trade unions, which are doing some very useful work with the employer side on that, and I am hopeful that we can conclude our work on a series of workstreams, including proper career paths, including issues around model contracts which, whilst retaining flexibility, provide some consistency around pay. We need to conclude that piece of work early in the autumn, October time roughly, but this is an area where to some extent we are an extremely interested observer and occasional broker, but the real work is being done between the employee and the employer whom we bring together in WAMG. As I said earlier, we have got a very positive social partnership which I am optimistic can resolve some of those issues and I want to ensure that the good questions which you raised in terms of technicians are addressed through that and that we are then able to recruit into it, provide the progression through to higher level teaching assistants, who then in turn will be able to work in the classroom directly with children, which I think will give them great satisfaction and allow them to use their enthusiasm for science more effectively.

*Ms Bramman:* In 1997 there were 12,700 science technicians; currently there are 23,000 science technicians, so that has almost doubled in the last 10 years.

**Lord Taverne:** One last question about the curriculum. I take the point you made earlier that you need the maximum amount of autonomy to look at

schools, but in a science curriculum I think it is a reasonable thing for the department to ensure that when science is being taught, science is being taught, not pseudo-science. What guarantee have we got that we will not see the teaching of intelligent design or creationism in any of our state-funded schools—

**Lord Howie of Troon:** Hear, hear!

**Q65 Lord Taverne:** —or any sort of control over the curriculum?

*Lord Adonis:* We have a National Curriculum which sets out the requirements very clearly in this respect and schools are expected to stick with it. We now have a National Inspectorate, which of course again is a development on that last 15 years, which inspects every school against the curriculum and reports. So I believe we have a pretty effective system in place to see that the science which is taught is science.

**Q66 Lord Taverne:** But there do seem to be cases in the North East where intelligent design is being taught.

*Lord Adonis:* Actually, I think I probably should copy you in on correspondence I have had with other Members of the House on that. I think you are talking about one particular school. In fact that is not the case in science lessons, and indeed that particular school has had very positive Ofsted reports, including on the teaching of science. So I think it is one of those cases, my Lord Chairman, where not everything in the *Guardian* is true!

*Jim Knight:* Not everything in the *Guardian* is rosy!

**Lord Howie of Troon:** Check the football results!

**Q67 Chairman:** We very much appreciate your coming to talk with us. I am sorry we were interrupted several times, but that is the way this place works. Of course, if you need to say more to us, please write to us and we would appreciate any additional input you might want to make.

*Jim Knight:* There is some further information from the Training and Development Agency around returners, which I will certainly write to you on, which I received during one of our little interregnums.

**Chairman:** Thank you all very much indeed.

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WEDNESDAY 5 JULY 2006

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Present	Broers, L (Chairman) Finlay of Llandaff, B Howie of Troon, L Mitchell, L	Patel, L Paul, L Platt of Writtle, B Selborne, E
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### Memorandum by Ofsted

#### 1. THE CURRENT SITUATION

1.1 Recruitment and retention of teachers in science remains a problem. In the last published report from HMI (2004–05) the decline in supply of teachers was described using data provided by The Department for Education and Skills: “Since 1998 the teacher vacancy rate has nearly quadrupled and in January 2005 the number of unfilled posts was 250, the highest for any subject.” These shortages are seen to be at their most severe in the south east of England and metropolitan areas. Evidence from inspection indicates that Science Specialist Schools and schools with sixth forms find the recruitment of staff less problematic. Inspection evidence also indicates a strong correlation between the match of the teachers to the curriculum and the quality of teaching and hence the achievement of pupils.

1.2 There is also evidence from inspection that not all science teachers are confident to teach across the whole science curriculum. This has implications for the provision of continuing professional development.

#### 2. TEACHING SCIENCE

2.1 The pattern of professional development has changed over the last decade. The number of Local Authorities that offer subject specific advice and guidance has declined and schools have increasingly looked elsewhere for subject training. Teachers have told inspectors of the low levels of continuing professional development on science specific topics.

2.2 The Secondary National Strategy has brought about improvements in planning, the clarity of lesson structure, the use of learning objectives and the attention given to assessment that informs the learning of pupils.

2.3 The science education community collaborates well to offer teachers support and guidance. The good collaboration within the science education community is exemplified by the collaboration between the Qualifications and Curriculum Authority, Ofsted, Secondary National Strategy, National Advisers and Inspectors Group, and the Science Learning Centres. These organisations held a series of conferences, which were judged to be highly successful by delegates, to prepare teachers, schools and Local Authorities for the changes to science National Curriculum with new GCSEs in September 2006 and a new Programme of Study for Key Stage 3 in September 2008. Both these changes involve a strengthened emphasis on “How Science Works”. This change of emphasis is broadly welcomed by science teachers.

2.4 There is a strong correlation between successful teaching and learning in science and engaging pupils in investigative work similar to that carried out by practising scientists. Thus “How Science Works” is not confined to carrying out practical science but is rather a broader experience of work in science, including preparation for continuing science education and work. This involves pupils developing the skills of scientific enquiry, and, through analysis of evidence, arriving at a new understanding of the world around them. The components that promote a good environment for effective teaching and learning in science are: planning for progression in pupils’ learning; assessment of knowledge, understanding and skills to inform pupils’ learning; monitoring and evaluation including the analysis of data to identify both successes and areas for development. These elements combine to support exciting teaching and to promote pupils’ engagement and enjoyment of science.

2.5 Teachers express a desire to work in high performing departments. Where standards of science education are high there is often well developed collaborative planning resulting in a scheme of work that provides good support and guidance on different units of work. Such planning does not stifle innovation by individual teachers, but promotes variety of approach and the sharing of good practice. Effective schemes of work show links to other curriculum areas, such as literacy, numeracy, information and communication technology and

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personal social and health education. In effective science departments innovations are shared, for example, at departmental meetings and through peer observations. The monitoring and evaluation of teaching through observations, and through analysis of assessment data, affirms the impact they have on learning. There is an ethos of developing staff and sharing expertise.

2.6 Science education does not begin in the secondary school. There needs to be progression in learning from primary school through to post-16 courses. Good teaching builds upon pupils' achievements and involves planning courses of study that meet their individual needs. Too often pupils face the experience of repeating work from earlier in their education with insufficient challenge to promote further learning.

2.7 The provision and deployment of laboratory technicians and teaching assistants is a matter for schools to decide. As a consequence there is great variety of provision. In the best practice laboratory technicians support pupils during science activities and many derive increased job satisfaction from this aspect of their work. There is scope for science specific training for classroom assistants to enable them to take on a more effective role in the science classroom.

### 3. SCHOOLS

3.1 The last Her Majesty's Chief Inspector's Annual Report (2004/05) commented on the impact of the poor condition of school laboratories: Ofsted inspection shows that around two fifths of schools have accommodation for science which is good or better. In too many schools, however, accommodation remains less than satisfactory.

3.2 Ofsted's inspection data show a clear positive correlation between the quality of accommodation and the quality of teaching. Where accommodation is less than satisfactory, it hinders teaching and learning. There is therefore a clear need for improved standards of accommodation.

3.3 Schools that have achieved Science Specialist School status have benefited from additional funding. This has often been used to refurbish laboratories and build up resources. As yet the impact of specialist status on the value added performance of these schools is not clear.

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#### Examination of Witnesses

Witnesses: Ms MIRIAM ROSEN, Director of Education, Ofsted, and Mr IAN RICHARDSON, Specialist Subject Adviser for Science, Ofsted, examined.

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**Q68 Chairman:** Let me welcome you to this meeting of the Science and Technology Committee, Ms Rosen and Mr Richardson. Thank you very much for coming to give evidence today. This is the second of three public meetings that we are holding in this short inquiry into science teaching in schools. For those of you from the public who are here, there is a document there that informs you about the inquiry. Before we start, may I ask everybody to speak up. This room has rather poor acoustics and it is not easy to hear what is said. To open, would you please introduce yourselves and, if you wish, make an opening statement. If you do not wish to do so we will go straight into our questions.

*Ms Rosen:* Thank you. I am Miriam Rosen. I am Director of Education at Ofsted and after my colleague has introduced himself I will make an opening statement.

*Mr Richardson:* I am Ian Richardson. I am the Specialist Subject Adviser for Science.

*Ms Rosen:* In September 2005 Ofsted introduced a new lighter touch inspection system for schools called the section five inspections. Schools now have shorter

inspections lasting two days only and they receive shorter notice. The inspections are lighter touch, focusing on the central nervous system of the school. Inspections are now more frequent. Each school is inspected in a three-year cycle thus providing parents and others with more up-to-date information. Overall, the new inspections have reduced the cost and burden of inspection and have been introduced successfully. Ofsted has just consulted on reducing the weight of inspection even more for higher achieving schools. From September 2006, 20 per cent of schools, that is higher achieving ones, will receive a very light touch inspection lasting only one day. The short section five school inspections do not include inspection of subjects of the curriculum. Ofsted has instead initiated a separate subject inspection programme to gather evidence which will allow Her Majesty's Chief Inspector to report on and offer advice on subjects. A sample of 30 secondary schools and 30 primary schools is visited for each subject each year. This sample is not statistically significant but it contains a range of schools in terms of the socio-economic context, school size, type and geographical location. The subject inspections allow strengths and

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weaknesses and emerging issues to be identified and matters of particular interest to be followed up by inspectors. Specific issues will be reported in HMCI's annual report and every three years on a rolling programme an overview report will be published on each subject. The first science report in this series will be published in the financial year 2007–08. The annual report for primary science in 2004–05, which is the last year when the older style fuller section 10 inspection evidence was available, reported that two-thirds of teaching was good or better and that where the teaching was weaker, subject knowledge was inadequate and expectations too low. The secondary report for the same year reported that teaching was good or better in nearly three-quarters of schools and that there is very little unsatisfactory teaching. I might say a little bit about teacher vacancies and mobility. Taking a more detailed look at the DfES's figures on teacher vacancies on science, which were quoted in our written statement, they showed that they rose from 1998 to 2001. Since then they have fallen although they remain at a higher level than in 1998. Ofsted's overall evidence on teacher shortages and mobility taken from secondary inspections in 2003–04 and 2004–05 indicates that there are wide variations across the country. London has the highest average percentage of posts unfilled. The rates of teacher mobility vary greatly from school to school from almost no turnover to over 70 per cent in some schools in the South East. High levels of teacher turnover and vacancies were most prevalent in areas of greater deprivation and in urban areas. There is a clear correlation between higher teacher mobility and less favourable inspection judgments on key aspects of school performance. In schools with high teacher mobility the subjects most affected are English, mathematics and science. In science, in schools with higher teacher mobility, the match of teachers to the demands of the curriculum was unsatisfactory in 14 per cent of schools compared with 3 per cent of other schools. Similarly, the proportion of unsatisfactory science teaching was greater in schools with high teacher mobility at 12 per cent compared with five per cent for other schools. That finishes what I wanted to say initially and I will be very pleased to answer questions.

**Q69 Chairman:** Thank you. To what extent will the new testing system be able to reveal specific subject weaknesses in individual schools?

*Ms Rosen:* The new testing system?

**Q70 Chairman:** I understand that the inspectors no longer report in detail on school subjects in individual schools, that you are generalising it into an overall evaluation. My question is how will that handle the individual problems in an individual subject in the school?

*Ms Rosen:* We do not look specifically at the subjects of the curriculum when we inspect individual schools; however, because we look at the overall health of the school and we start with the school self-evaluation and with the data that there is, we analyse that and we look to see what the issues are in that particular school. When we go into the school to start the inspection we then follow those up. If a subject like science was clearly showing as a weakness in that particular school it would be followed up because it would impact on the overall health of the school.

**Q71 Baroness Finlay of Llandaff:** In your written evidence, you have stated that science faces the highest teacher vacancy rate of any subject. I wonder if you can tell us why this is a particular problem for science and why the science teacher vacancy rate has risen so substantially in the last decade.

*Ms Rosen:* First of all, I would like to say that although the science teacher vacancy is higher now than it was in 1998, I would like to go back to my original statement and say that it rose up to 2001 and it has been falling again since then. Of course, we cannot say exactly why it is on the rise. We can say that overall scientists have a choice of jobs which they can go into and overall, perhaps, science teaching is not attractive enough in competition with these other jobs. However, we would like to acknowledge that there have been initiatives which have tried to reverse this trend, such as “golden hellos”. I will pass over to Ian Richardson who can give us a little more detail in this area.

*Mr Richardson:* Because of the programme of subject visits that take place now to inform HMCI's annual report, I talk with teachers *in situ* and they tell me of the issues they face and the things that have influenced them to take up teaching. We do not have direct data, we do not collect it as part of the inspection practice, but we do have access to the DfES data and what teachers tell us is that they have been attracted to science teaching through incentives like “golden hellos” and competition in the workforce distribution over the country because when it is more difficult to get employment in mainstream science activities, they take a more serious look at teaching. We do not have quantitative data to offer you.

**Q72 Baroness Finlay of Llandaff:** Has any work been done looking at recent graduates to explore across the board how they would view a career in science teaching so you get some idea of the ones who do not come in as well as information from those who have been attracted by the “golden hellos”?

*Mr Richardson:* We have no programme to do that because that is the responsibility of other agencies to recruit, to attract and to look at teacher retention. We look closely at schools and the information we

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pick up as we do that we are happy to pass on, but it is not quantitative and it is not closely looking at the attraction and retention issues.

*Ms Rosen:* One thing I would like to add, if I may, is that we do see young graduates who are extremely enthusiastic about teaching science and doing very well.

**Q73 Lord Howie of Troon:** I think you said you did not know why. Have you tried to find out why or is that wholly outside your remit?

*Ms Rosen:* Our remit is concerned with the standards of teaching in schools and we look at the effectiveness of what we see. In my introductory statement, as I said, in the majority of primary and secondary schools the teaching of science is good. There is, of course, about a quarter of secondary schools in which we would class the teaching of science as satisfactory. There is not a great deal of unsatisfactory teaching. We are in there looking at what we see and the effectiveness of what we see. We are not particularly chasing down the issue of teacher vacancies. One thing we would say, however, is that where we see good science teaching it clearly has an impact on the enthusiasm of the pupils.

**Q74 Lord Howie of Troon:** I still think you should worry about why things happen.

*Ms Rosen:* I think we have an awful lot of pulls on our time and we have to decide what it is that we look at. There is another agency which, in particular, is looking at the attraction of graduates in science and/or into other subjects, so I think we are staying reasonably within our remit and are focusing very hard on the overall effectiveness of schools and the teaching in schools.

**Q75 Baroness Platt of Writtle:** What impact is the shortage of specialist physics and chemistry teachers having upon the quality of teaching and, following on from that, the effective engagement of pupils in these subjects?

*Mr Richardson:* These data have been gathered through the previous inspection system, section ten, to give us detailed data that shows a clear correlation between the match of teachers to the specific curriculum components within the science field and the success stories, the quality of teaching and the success of pupils as measured by their achievement. This scrutiny of standards, and of what pupil achievement is, continues under the subject inspection framework which is now in place alongside the section five work and it continues to show us that in places where teachers are teaching their own subjects, particularly in Key Stage 4 alongside the GCSE courses, then there is a good correlation between teachers matching the curriculum, in physics, chemistry and biology, and

successful outcomes in terms of achievement for those pupils.

**Q76 Baroness Platt of Writtle:** Is training science teachers to teach outside their specialism a satisfactory substitute for employing someone with an academic qualification in a relevant subject? We have had a good deal of evidence as you know from the Royal Society of Chemistry, the Institute of Physics and the Biosciences Federation and the biological sciences people are saying how difficult it is to switch to, say, physics and chemistry where the larger vacancies are.

*Ms Rosen:* Can I start by saying that for some people their background is sufficiently broad, although they have a specialism in one particular subject, for them to be able to teach competently across quite a broad range. Topped up by professional development that is going to make them very successful, but for other people it is more difficult so it does rather depend on the individuals and for some individuals it may be very hard if they are biology specialists to be teaching the physics component, let us say, up to Key Stage 4. For the majority, that would be extremely difficult and professional development can only address that to a certain extent. We would agree that it is necessary to have a range of science specialists available.

**Q77 Lord Paul:** What is your assessment of the retention rate of science and mathematics teachers, particularly in the early part of their careers? From your conversations with teachers, what do you think are the key drivers behind teachers leaving the profession and how can that be addressed?

*Mr Richardson:* Ofsted, as part of its inspection practice, does not collect data directly on retention rates, but when we are in schools talking with teachers we do pick up qualitative information that illuminates the question you have posed to us. Speaking with young teachers they can, in their first year of employment, be rendered very vulnerable if they are not in a good supporting department. They can feel very exposed and if they do not experience a match between their aspirations to become a teacher and the reality of being a teacher, they become disappointed with the experience. It is one of the reasons given to me that they leave the profession early. The lure of other employment that is more handsomely rewarded financially has also been cited to me and for some teachers who are perhaps less committed at the start of their teaching career, they make an assessment of the work life balance which they are experiencing and decide that the teaching challenges are more than they wish to take on long-term and so remove themselves from education. We think those are qualitatively causal factors for them leaving. Differential retention rates between subjects



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is something that we do not look at, it is other agencies that quantify that matter.

**Q78 Lord Paul:** We got the impression that the retention in science and mathematics is much less than in other subjects. Have you not done a study as to why?

*Mr Richardson:* We do not study that directly, we do not gather that data.

*Ms Rosen:* May I add something to that. We did look under section 10 inspection at teacher mobility and there was higher teacher mobility in areas like science and maths than other subjects.

**Q79 Lord Paul:** What evidence, if any, have you seen of teachers being adversely affected by an overload of initiatives from the Government? Have they been given sufficient time and support to prepare for the new GCSE courses starting in September?

*Mr Richardson:* Schools have a considerable degree of autonomy so when they evaluate the continuing professional development needs of their staff they then have the responsibility of finding a source for that training. Clearly, centrally some organisations have offered start-up sessions that help schools and people in local authorities to think through the issues around some of the major changes, principally at the moment the introduction of the new GCSEs that are happening from September, but the responsibility of identifying CPD for those staff is that of the school and they have the freedom to use their resources in whatever way to support staff. I have seen some very strong examples where leadership and management of schools have very carefully measured the skills and talents and preparedness of teachers to face these changes. They have analysed the changes and have done a considerable amount of good quality work to ensure that their staff receive the right training for the introduction of the new GCSEs. The standard across the piece I do not see universally to be the same.

**Q80 Lord Paul:** How often do you encourage schools to interlink and interact with each other?

*Ms Rosen:* We inspect individual schools but we do look at what sort of links they have. I think what we are mainly looking at though is how well they are being enabled to fulfil their main purpose, which is teaching and enabling youngsters to learn. If they are doing that by their own resources or by linking with others, I think what we are mainly concerned about is the outcome.

**Q81 Lord Paul:** I want to know because if you went to a school where you found the teaching was excellent, do the inspectors go to the other school and say "We came back from that school, they were marvellous. What can you learn from them?" or vice versa?

*Ms Rosen:* By the publication of our reports we do spread good practice. As well as the individual reports on schools, which are published, we also particularly pick up good practice through survey reports and they are published and give examples in them which we do hope schools will learn from.

**Q82 Earl of Selborne:** Are you satisfied with the specialist schools systems and the academies which are, after all, meant to be exemplars which other schools benefit from, that the ripple effect is, in fact, happening or do you find it is confined within a narrow geographical area?

*Ms Rosen:* We do not have evidence on that at the moment. We published a report on specialist schools about 18 months ago where we did find that the schools were starting to have an impact but the community dimension was slower off the ground than other dimensions. We have not published anything recently on it.

**Q83 Chairman:** In line with that, have you seen evidence that specialist schools do well in their non-specialisms as well?

*Ms Rosen:* Again, we have not got recent evidence on that. Where schools are good they tend to be doing well in other subjects as well as their specialist subjects. It really boils down, as is so often the case, to the effectiveness of the leadership and the management in a particular school.

**Q84 Lord Howie of Troon:** Mr Richardson mentioned continuing professional development. Is subject-specific CPD a good idea and, if it is, do you think that science teachers should be entitled, or even required, to undertake some every year or at some point?

*Mr Richardson:* We believe that well focused, well planned CPD can have a very positive impact on the quality of work that goes on in science departments in schools. I will just remind you that schools are free to put on whatever CPD they wish and it is the schools where leadership and management is strong that take care to analyse those professional development needs. There is a wide range of providers out there: the learned societies, the new network of national learning centres and regional science level centres put on courses to support such development. It is up to the schools to decide where they source courses from and how much CPD goes on. We would endorse the idea of an entitlement to good quality CPD for teaching colleagues in science no less than other subject areas. At the moment when I go into schools I encounter a very variable picture in which the majority of science teachers I talk with say that they are not experiencing the quantity and quality of subject CPD that they would wish for.

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**Q85 Lord Howie of Troon:** There is a problem, of course, of cover for teachers who are off on a course during term time. Do you think it would be feasible or even desirable to induce them to undertake these courses in what might be described as their holiday?

*Ms Rosen:* I think that you can think about how you incentivise teachers to take up CPD but the point that I would most like to make is that where CPD has the greatest effect is where it is matched to the needs of the individual teacher and this boils down to the school identifying what the needs are and for one particular teacher it may well be subject-specific science CPD, for another it may be something quite different, such as behaviour management, and ensuring that CPD is provided. I do not think it is a case of one-size-fits-all. It is a case of identifying the needs and then ensuring that those individual needs are met.

**Q86 Lord Howie of Troon:** What do you do with a teacher who will not have it? In the outside world you get the sack.

*Ms Rosen:* If a teacher is not competent and decides that they do not wish to accept the advice and support that the school is offering to them then the school should have a way of dealing with that. The majority of teachers are keen to improve but also the school has open to it its performance management system which should be very closely linked to effectiveness in the classroom and what we are saying about where CPD is effective is where it matches the needs of that individual in order to help them improve their performance in the classroom.

**Q87 Earl of Selborne:** Mr Richardson referred to the national network of Science Learning Centres which appear to be doing a very good job in development of science teachers' professional development. As he said, schools are at liberty to decide where they do the CPD training and some will choose to do in-house and have every right to do so, but if they are the very schools which are short in, for example, science teaching, to do that training in-house seems to be unwise. What can be done to promote the new Science Learning Centres to the schools who need them most?

*Mr Richardson:* I know the National Science Learning Centre currently has a policy of subsidising courses to encourage teachers to come out of schools and to encourage head teachers to let teachers come out of schools to attend courses. A lot of their effort is going into the attraction of secondary phase teachers. I am aware of them encountering difficulty in filling courses for secondary phase in science development. Again, we do not inspect that area of operation directly but I am aware of those data. They are trying a range of attractions, not only subsidising courses but offering accreditation for such courses.

They are trying to get teachers to engage with a website so they connect with what is going on in the Science Learning Centres. Miriam used the word "incentivise". I know they are very keen to look for incentives that will help people come out of schools. As yet, we do not have directly observed data on the success or otherwise of those strategies.

**Q88 Lord Mitchell:** I would like to ask about laboratory technicians. In your evidence you pointed to a great variety in the provision of lab technicians between schools. I want to know what is the impact upon science teaching of having too few of them, many of whom, of course, are part-time anyway?

*Mr Richardson:* Again, the schools have responsibility for how many staff to employ alongside what general criteria. Our experience is that in schools where the staffing for lab technicians is low in proportion to the number of laboratories and the number of teachers that it can have a number of effects. One is that if teachers want to pursue well-crafted science activities they are faced with preparing the materials themselves which depletes the time they have available for addressing assessment issues and addressing planning issues and provision of the stimulus materials to go alongside that activity that can interfere with the success of the lesson. I do come across teachers who, when technician support is lighter, withdraw from doing practical work and therefore revert to a rather more didactic approach to the teaching of science with a reduction in the proportion of science activity that could be described as science investigation or exploring how science works.

**Q89 Lord Mitchell:** Do you think there should be a requirement to have a minimum number of technicians at schools according to the number of pupils who are doing science?

*Mr Richardson:* It is certainly something that school management and the leadership and management of science departments ask for. Many schools I go into ask me what my recommendations are. We do not offer recommendations. As part of the inspection process we can talk about how such resources may be managed but there is no algorithm, no formula to offer them about what staffing as regards assistance should be, and indeed under workforce reform the range of work that laboratory technicians have done has expanded to involve more administration and some in-class support working alongside pupils to make sure activities are successful.

**Q90 Lord Mitchell:** I was just going to ask a slightly different question, if I could, if that is alright Lord Chairman: anecdotally or instinctively, do you feel that schools that are using information technology in general, not in science but in general, using intelligent

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whiteboards and the like, have better results when it comes to science as we are looking at now? Is there any evidence of that?

*Mr Richardson:* Anecdotally.

**Q91 Lord Mitchell:** Anecdotal evidence.

*Mr Richardson:* I see some very strong examples of schools and in particular science departments who have embraced the capabilities and possibilities of interactive whiteboards, et cetera, to provide very much more stimulating and engaging environments for learning science. There are some very dramatic examples where students' engagement and enjoyment has lifted because of judicious and skillful use of ICT interactive whiteboards and a range of other ICT applications and devices. There is a rich source of anecdotes.

**Q92 Lord Patel:** It is a related question on technicians in science. A lack of lab technicians, as you clearly indicate, could lead to more didactic teaching in science, which probably makes the pupil less interested in taking science, or maybe even teachers are not promoting students to take up science. In terms of looking at solutions, have the schools looked at what are the causes as to why they do not attract technicians?

*Ms Rosen:* If I may start on that one. It is up to the head teacher of the school how they spend the school's budget and which staff they employ, so I think it is down to what the head perceives as being the needs of the school as to how many science technicians they will employ, rather than technicians choosing not to take up jobs.

**Q93 Lord Patel:** I see, so it is not that there is a lack of technicians available; it is that the heads are choosing not to go down that path, which then leads to less take-up of science in schools?

*Ms Rosen:* Well, I think the way you are linking those things together is not quite a causal link in that way. If you are thinking about why do young people perhaps not progress into A level science—and I think that is probably what you are talking about, is it not—then there is a variety of causes there. One of them will be whether or not they have received really interesting and inspiring teaching lower down the school, and that is due to a number of factors such as the skill of the teacher. Is the teacher engaging? Is the teacher able to put on practical work? Has the teacher got a fund of interesting ways of putting their subject across? So it is a whole range of things. It is not a direct causal link back to lack of science technicians.

**Q94 Lord Patel:** No, but in your evidence you do say that if there is a lack of technicians teachers may well go down the route of didactic teaching, making science teaching less exciting to the pupil?

*Ms Rosen:* Yes, but I think what I am trying to say is it is one of a number of factors because you also need committed teachers who have the ability to teach in an interesting and inspiring way.

**Q95 Chairman:** Thank you very much indeed for answering our questions, Ms Rosen and Mr Richardson. You do realise that if things occur to you that you would like to tell us when you have left this meeting, we are very happy to accept additional input from you. Thank you very much indeed.

*Ms Rosen:* Thank you.

### Memorandum by the Royal Society of Chemistry

1. The RSC is the largest organisation in Europe for advancing the chemical sciences. Supported by a network of over 43,000 members worldwide and an internationally acclaimed publishing business, our activities span education and training, conferences and science policy, and the promotion of the chemical sciences to the public. The RSC, either on its own or with others, commissions research projects into aspects of education where evidence is apparently not available from Government, but is, in the RSC's view, in the public interest.

### 2. THE CURRENT SITUATION RELATING TO TEACHER DEPLOYMENT AND SUBJECT SPECIALISM

This is covered in the DfES sponsored NFER report "Mathematics and science in secondary schools: the deployment of teachers and support staff to deliver the curriculum" which builds on earlier findings such as Chemistry Teachers (RSC 2004) (<http://www.rsc.org/Education/Policy/Supply2004.asp>) and the Parliamentary Office of Science and Technology Technical Report 88 (December 1996) which even then highlighted future shortages of qualified teachers in the sciences.

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*The NFER report*

During the academic year 2004–05, NFER investigated the deployment in mathematics and science departments in one in four maintained secondary schools in England. The evidence was collected via a postal questionnaire to departmental heads and teachers of mathematics and science; a postal and telephone survey of support staff who assist in these departments; and case-study visits to 12 departments, deemed by their local authority to exemplify good deployment practices in mathematics and science.

The report indicates that only a quarter of UK secondary school science teachers have a chemistry specialism and less than a fifth have a specialism in physics. This is in contrast to 44 per cent of science teachers with a specialism in biology. In addition, the survey found that 8 per cent of those teaching science are non-specialists or are principally teachers of other subjects.

**Table 1**

**SPECIALISMS\* AND EXPERIENCE OF ALL TEACHERS TEACHING SCIENCE ACCORDING TO DEPARTMENTAL HEADS**

*Mathematics and science in secondary schools: the deployment of teachers and support staff to deliver the curriculum*

<b>Members of science departments</b>	
<i>Teachers with a specialism in:</i>	
Biology	44%
Chemistry	25%
Physics	19%
Other science	5%
Non-science-related subject	20%
<b>Members of other departments</b>	
Teachers who mainly teach other subjects teaching science	6%

\*Specialism was defined as “holding a degree in the subject or specialising in the subject in initial teacher training”.

The data also showed that the imbalance in the representation of biology, chemistry and physics specialists was unevenly spread across schools. Teachers with a degree in chemistry or physics were more widely represented in 11–18 schools compared with 11–16 schools. Also, schools with higher than average GCSE results and lower than average numbers of pupils eligible for free school meals tended to have a higher proportion of teachers with a science degree.

**Table 2**

**PROPORTION OF DEPARTMENTS WITHOUT ANY SPECIALISTS IN BIOLOGY, CHEMISTRY AND PHYSICS**

<i>Specialism</i>	<i>All schools (%)</i>	<i>11–16 schools (%)</i>	<i>11–18 schools (%)</i>	<i>Other schools (%)</i>
Biology	1	1	0	0
Chemistry	7	12	4	2
Physics	16	26	10	6

The results show that there are some schools without a single appropriately qualified chemistry or physics teacher and a substantial number in which the majority of Key Stage 3 and Key Stage 4 science lessons are taught by biologists or those without a mainstream science qualification.

A further concern is the fact that the age profile of science teachers is unbalanced towards the high end. This will have serious implications for the continuity of passing on the craft of the classroom.

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### 3. ATTRACTING SCIENCE TEACHERS TO THE PROFESSION

There can be little doubt that the various initiatives such as training bursaries and “golden hellos” have been successful in attracting people into science teaching. There remains, however, the major problem that recruitment remains supply led rather than demand led, that is more biology graduates enter initial teacher training than do physical science graduates whilst the evidence from the report in Section 2 above indicates that biologists should be a minority of the entrants.

The figures for 2005 are:

Chemistry	575
Biology	996
Physics	428
Combined Science	1,012

Historical data for chemistry are at [www.rsc.org/images/4TeacherTraining\\_tcm18-38626.pdf](http://www.rsc.org/images/4TeacherTraining_tcm18-38626.pdf)

Some measures are being taken to increase the numbers of teachers with appropriate qualifications and/or training to teach physics and chemistry. The Physics and Chemistry Enhancement courses funded by the TDA have started to increase the pool. The proposals in the “Science and Innovation Investment Framework 2004–14: next steps” (March 2006) to increase the per cent of science teachers with a physics specialism from 19 to 25 per cent by 2014, and those with a chemistry specialism from 25 to 31 per cent are laudable, but short on detail. Whilst it is true (6.19 p 44) that “there is a good supply of relevant science CPD” it is unsurprising that with respect to the regional Science Learning Centres that take up on these courses has been slow with limited results so far when these providers are both new entrants to the market and there is no entitlement for science teachers to undertake subject specific CPD. (The RSC has not noticed any appreciable slacking in demand for its subject specific CPD in recent years.)

The proposals (Box 6.2, p 45) to develop and pilot a CPD programme leading to an accredited diploma to give existing science teachers without a physics and chemistry specialism the deep subject knowledge and pedagogy to teach these subjects effectively and to remit the Schools Teachers’ Review Body to advise on whether such people should receive an incentive are welcomed. However it is unclear how Headteachers and schools will be persuaded to release teachers to train, who will provide the training, the nature of any accreditation and the demand from the teaching force for training. There is also no consideration of how any of this is managed—from development to implementation. The RSC suggests that experience from the TDA enhancement courses strongly favours involvement of the professional bodies.

### 4. TEACHING SCIENCE

The RSC will comment here only on the importance of specialist teaching, the role of the practical in teaching science, and on the relative difficulty of science subjects at GCSE and A-level.

Ofsted has commented on the positive correlation between the subject knowledge of teachers and the proportion of excellent/good lessons as measured by the inspection criteria. It is imperative, therefore, since there is clear evidence from the NFER report that much science teaching is carried out by non-specialists, that steps are taken to provide subject specific CPD for science teachers. Whilst the recent announcements about a diploma are a step in the right direction, until there is an entitlement for science teachers to engage in subject specific CPD, progress will be limited.

There can also be little doubt, from Ofsted and other evidence, that practical work in school science has suffered for two main reasons:

- (a) the drivers for teachers to obtain good results in external assessments in years 9, 11, 12 and 13 has meant there has been teaching to the test, spending more time than previously on revision and seeing non-assessed practical work as something that can be reduced; and
- (b) the formulaic nature of GCSE assessment has led to a narrowing of the type of practical work undertaken.

Recent changes to the science curriculum at GCSE for first teaching in September 2006 have led to an increasing emphasis on “How Science Works” and the provision of courses both for those who are to be informed citizens in a scientific and technological society and those who are to be future scientists.

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The RSC is clear that all these changes require practical work in its widest sense—investigation, experimentation to confirm known facts, handling of a wide range of data, including ICT, and working in teams. What is unclear is the role of the Qualifications and Curriculum Authority (QCA) in monitoring the Awarding Bodies to ensure that assessments reflect the Programme of Study or KS4 and its emphases.

There are many existing schemes designed to help generate enthusiasm in young people for science subjects. Indeed the recent DfES STEM Mapping exercise indicates that there may be too many and they may be too disjointed. There are, however, other factors that may inhibit choice, if not enthusiasm.

There has been clear evidence from matched pair analysis for over 10 years, from the Dearing Review of 1996, through the work of ALIS and the Curriculum, Evaluation and Management Centre at the University of Durham that both GCEs (A-level) and GCSEs in Science subjects are more difficult than many others. Thus students may well realise that if they need particular grades or UCAS points for entrance to higher education then chemistry or physics may not be the best choice. The QCA has addressed the issue of standards over time but has not addressed the issue of cross-subject comparability.

A further limiting factor on choice is the ignorance within the education system about the careers (and rewards) that can be achieved from a study of science, both within and without science. This was recognised in the “Science and Innovation Investment Framework 2004–14” by the promise to establish a careers from science website under the auspices of the Science Council. Despite sizeable financial contributions from the RSC, and the Institute of Physics, the Royal Society and the Science Council, government has failed to offer any support to realise this project.

## 5. SCHOOL ACCOMMODATION AND RESOURCING

Classroom practicals form an integral part of many science courses. Teachers are encouraged to include them in their teaching by both examination specifications and national schemes of work (guidelines which help schools implement the national curriculum). In addition, studies have shown that practical and investigative work has a marked positive effect on pupils’ enjoyment and learning of science.<sup>1</sup>

Although the UK has an excellent record in international comparisons in school science, a succession of reports have highlighted concerns about both the science curriculum and the facilities and resources available for science teaching.<sup>2,3</sup> In 2003, the RSC decided to commission its own study into the current state of school science laboratories. Given the importance of classroom practicals in enhancing pupils’ experience of science, the RSC was worried that a lack of good facilities and modern equipment in schools may be turning young people off pursuing the study of science. It was also anxious that these factors might discourage science graduates from taking up a career in teaching.

The RSC asked the CLEAPSS School Science Service (the Consortium of Local Education Authorities for the Provision of Science Services—an advisory body supporting the teaching of practical science) to undertake an investigation into whether these concerns were justified. The work was divided into two main projects; the first (“the Lab Project”) looked into the current standards of science laboratories and resources and the levels of budgets required to make improvements where necessary. The second project (“the Resource Project”) set out to determine the cost of providing apparatus, resources and chemicals needed, per pupil, to provide an effective science education. Research was then carried out to see how this related to actual provision made in schools. In April 2004 the final report was published, entitled “Laboratories, Resources and Budgets”.

CLEAPSS sent questionnaires to every maintained school in England. Half of the schools in each of the 148 Local Education Authorities were sent a questionnaire relating to laboratories, the other half received one relating to resources and budgets. High levels of return for both surveys (42 per cent on the Lab Project and 26 per cent on the Resources) give high confidence in the results and provide an indication of the importance that schools place on this matter.

The results of the Lab Project make unsettling reading, with only 35 per cent of school laboratories in the sample rating good or excellent. 41 per cent were rated as basic and uninspiring, and an alarming 25 per cent were rated as unsafe or unsatisfactory. Teachers also reported that, on average, one additional laboratory per

<sup>1</sup> *Students as “Catalysts” in the classroom: the impact of co-teaching between science student teachers and primary classroom teachers on children’s enjoyment and learning of science*, C Murphy, J Beggs, K Carlisle, J Greenwood, *International Journal of Science Education*, 26 (2004) pp 1023–1035.

<sup>2</sup> Ofsted Annual Report for 1997–98, 1999; *Set for success. The supply of people with science, technology, engineering and mathematical skills*. The report of Sir Gareth Roberts’ Review for HM Treasury, London, April 2002; *Science Education from 14–19. Third report of Session 2002–02 of the Science and Technology Committee*, House of Commons, London, July 2002; *SBS Survey of Secondary School Science Teachers*, SBS (The Save British Science Society), London, January 2004.

<sup>3</sup> *ibid.*

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school is required to allow all science lessons to be taught in a laboratory. This equates to an under-provision of at least 3,518 laboratories.

This means that, when pupils are in a science laboratory, their experience is unsafe, unsatisfactory or uninspiring for 66 per cent of the time (and this does not include the 13 per cent of the time that they are not in a laboratory at all).

Problems were also brought to light regarding the preparation areas that support science teaching and the storage and preparation space available to science technicians.

The research clearly showed that significant work needs to be done to bring many school laboratories, and the associated areas, up to a standard that will promote a positive learning experience to science students. This evidence provided RSC with a strong case to lobby the Government for such improvements.

<i>Laboratories</i>	<i>Number in sample</i>	<i>% in sample</i>	<i>Number estimated for all maintained schools in England</i>
Excellent	280	5%	1,315
Good	1,641	30%	7,770
Basic (uninspiring)	2,262	41%	10,695
Unsafe/unsatisfactory	1,386	25%	6,560
<b>Total</b>	<b>5,569</b>	<b>100%</b>	<b>26,340</b>

The cost of implementing the improvements required is substantial; if all issues are addressed at once, the total finance needed is estimated to be in the region of a staggering £1.38 billion. This represents the total cost to upgrade to a good standard only.

<i>Description of required improvement</i>	<i>Cost</i>
Upgrade all unsafe/unsatisfactory laboratories to a good standard	£361 million
Upgrade all basic laboratories to a good standard	£321 million
Build sufficient new laboratories	£510 million
Provide sufficient fume cupboards	£41 million
Upgrade all preparation areas to a good standard	£89 million
Extend all preparation areas	£24 million
Provide sufficient dishwashers	£6 million
Minimum cost of lift provision (to carry equipment between floors when laboratories exist on more than one level)	£28 million
<b>Total</b>	<b>£1,380 million</b>

Although the Government has committed £2.2 billion in 2005–06 to the “Building Schools for the Future” initiative—which aims to bring all school buildings in England up to a modern standard by 2015—none of this money has been ring-fenced for laboratories.

The results of the Resources Project indicated further shortfalls in funding. Over 90 per cent of schools who responded to the survey judged that the finances allocated were inadequate to sustain an effective level of science education. In some cases the situation was so severe that schools were not able to fully meet the requirements of the National Curriculum (especially in ICT) and practical work was being cut down.

According to the findings, the average amount made available to science departments in the 2003–04 financial year (in maintained schools) was just £9.89 per pupil. This is only slightly above the £9.40 average reported in a survey from 1998<sup>4</sup>, indicating that the increase in funding has not even kept pace with the rate of inflation (despite the rising cost of chemicals exceeding the inflation rate).

The low average amount per pupil is not the sole concern highlighted; there is also a surprisingly wide range within this sum—from £0.64 per pupil to £71.43. The authors of the report found it difficult to find justification of such extremes. There is a great worry that, at the lower end, the impoverishment of the curriculum is likely to affect pupils’ motivation and interest in continuing with the study of science.

The Resources Project also investigated the cost, per pupil, of providing the equipment, chemicals and biological materials required to teach science effectively. The estimates included an “essential” list of resources and a “desirable” list (the latter includes items necessary to teach science post-16, but which also enhance the curriculum in Key Stages 3 and 4).

<sup>4</sup> *Science teaching and resources: 11–16 year olds. The Survey Findings*, P Ramsden, *Education in Science*, 180 (November 1998), pp 19–21.



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Annual cost per pupil, 11–16	Classes of 24 pupils		Classes of 30 pupils	
	Essential	Essential + desirable	Essential	Essential + desirable
Estimated cost	£20.58	£17.28	£22.22	£30.75
Shortfall based on survey finding	£11.80	£20.36	£13.44	£21.97

There are just under 3 million 11–16 year old pupils in English secondary schools—around half of these are in classes of 24 and the rest in classes of 30. This means that science departments need approximately a further £37 million per year to provide the essential resources for teaching science; equivalent to an additional £10,000 per science department.

The survey also quantifies substantial shortfalls in post-16 work.

The final report was sent to Ministers, government departments, the science education community and all secondary schools in the UK. The results of the report have since been validated by the Ofsted (Office for Standards in Education) Chief Inspector's report for 2005.

The full *Laboratories, Resources and Budgets* report is available at [www.rsc.org/Education/Policy/Laboratories2004.asp](http://www.rsc.org/Education/Policy/Laboratories2004.asp)

## 6. TEACHERS' CONTINUING PROFESSIONAL DEVELOPMENT

There is a general misconception that teachers are entitled to subject specific CPD. This is not the case, although the recent draft standards for teachers from the TDA require subject specific CPD. If there was an entitlement then more teachers would have the opportunity to improve their subject specific knowledge and practice.

June 2006

### Memorandum by the Institute of Physics

#### INTRODUCTION

The Institute of Physics is a scientific membership organisation devoted to increasing the understanding and application of physics. It has an extensive worldwide membership (currently over 35,000) and is a leading communicator of physics with all audiences from specialists through government to the general public. Its publishing company, Institute of Physics Publishing, is a world leader in scientific publishing and the electronic dissemination of physics.

1. We assume that the inquiry will be looking at science education across the UK. We note that, although there are problems associated with science education in Scotland, they appear to be more successful in recruiting young people to study the sciences beyond the age of 16. We believe this to be because they have more specialist science teaching and smaller class sizes leading to an increase in active learning. We hope that the Committee will explore this aspect further and meet with representatives from Wales and Northern Ireland to explore the impact of the changes that are taking place there for example the removal of national testing and the breaking down of subject boundaries in the curriculum that are taking place there.

2. For the most part, our response refers to the situation in England, where it appears there are the most significant problems. Much of our response focuses on the teaching of physics rather than science. We think it is important to recognise that there are differences between the sciences, particularly when it comes to teacher numbers and participation. We feel that answers to the problems facing STEM education will only be found by understanding these differences.

3. We believe that the following are the key issues facing science education in schools:

- The Institute believes that the critical shortage of physics teachers in schools and colleges is the greatest threat to the future supply of skilled scientists and engineers. It is crucial that it is addressed at a national level.
- Parliament should investigate the crisis in teaching and address the five major deterrents—pay, conditions, status, workload and technical provision in schools.
- Government must accept and respond to market forces that dictate differential salaries for teachers in shortage subjects.

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- Government should set targets for the proportion of science classes taught to the 14–19 age range by subject specialists and collaborate with educational and scientific bodies to implement policies designed to meet the new targets.

## THE TEACHING FORCE

### *Numbers*

4. The shortage of well-qualified and enthusiastic physics and mathematics teachers means that the majority of the teaching of physics pre-16 is being carried out by non-specialists. Even though, as with other subjects, many of these teachers are committed and enthusiastic professionals, on average, they will not be able to impart the clarity and beauty of the subject with the same confidence that a specialist would. Inevitably, students will not be as motivated as in other subjects.

5. The serious shortage of physics specialists has been confirmed by the recent surveys by the University of Buckingham and NFER. The latter report found that only 19 per cent of science teachers were physics specialists and that 26 per cent of 11–16 schools had no physicist specialist in the science department. They also found considerable regional variation in the shortages and noted that the teacher age profile is such that we expect around a third of current physics specialists to retire in the next 10 years. So the situation is likely to become much worse.

6. Unfortunately, there does not seem to be good evidence about the retention of physics teachers. Anecdotally, in the same way that it is difficult to attract physicists into teaching because of their employability, so it is easier for them to leave teaching.

7. The Institute was very pleased by the government ambition to increase the proportion of physics teachers in schools to 24 per cent. But we are concerned that there does not seem to be a well defined strategy for achieving this goal and we are not convinced that the government will be in a position to know whether the ambition has been achieved or not unless they improve the quality of data on teachers.

### *Recruitment*

8. The number entering physics teaching varies cyclically, inversely correlating with the state of the economy, but remains low, averaging about 300 per year. This fails to maintain even the status quo and would need to be raised to 750, according to University of Buckingham report, to begin to address the imbalance between the sciences mentioned below.

9. Table 1 shows the recent recruitment to science and mathematics PGCE courses. Assuming a rough parity between the requirements for teachers in all science subjects, there must be a substantial and growing shortage of specialist physics teachers. Note that very few of those enrolling for Combined Sciences have a physics background.

**Table 1**

ADMISSIONS TO PGCE COURSES IN SCIENCE AND MATHEMATICS 1993–2004 (SOURCE: GTTR)

<i>Subject/Year</i>	<i>Physics</i>	<i>Mathematics</i>	<i>Chemistry</i>	<i>Biology</i>	<i>Combined Sciences</i>	<i>Total all subjects</i>
1993	568	1,469	578	730	282	16,938
1994	495	1,542	610	805	504	17,733
1995	420	1,470	528	791	650	17,209
1996	337	1,344	515	861	726	18,332
1997	277	1,150	409	901	740	19,297
1998	201	877	369	816	611	18,394
1999	245	1,142	390	849	699	19,007
2000	224	1,162	410	906	722	21,230
2001	242	1,311	469	913	743	22,223
2002	359	1,502	466	936	713	24,511
2003	399	1,858	501	938	851	27,459
2004	413	2,061	552	960	913	29,532

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10. In fact, the situation is worse even than the figures suggest. The numbers shown refer to trainees who are accepted to specialise in physics, of which only about 60 per cent were actually physics graduates in the 2001–02 intake. The rest were graduates of other science or engineering disciplines and, consequently, will have some serious gaps in their specialised physics knowledge.

11. With an average of only around 2,400 UK physics graduates each year, this shortage of teachers cannot be rectified from that source in the short to medium term, particularly when one considers the high financial rewards available to physicists elsewhere in the labour market. It is unlikely that the schools will be able to compete with the salaries available to physicists. One possibility that could be attractive is to pay off student loans after a certain length of time in the classroom. The Institute regrets that the DfES have discontinued the pilot scheme to write off student loans for PGCE students.

12. The Institute, with the help of the Gatsby Charitable Foundation, is taking a leading role in attempting to address these issues by supporting the Physics Enhancement Project. This is a Teacher Development Agency (TDA) funded project which aims to increase the number of trainee physics teachers by 200 a year from 2006.

13. The project takes graduates from science backgrounds who are not physics specialists. It provides them with an intensive six month course, typically from January to June, on subject knowledge, before they undertake initial teacher education (ITE). It also includes a wide range of support mechanisms including conferences, mentoring and a very substantial website, for the participants throughout their teacher training. This continues into the early years of teaching, to enable them to become established in their careers.

14. However, recruitment to the Project was fewer than 60 trainees in 2006 and recruitment to PGCE physics courses remained approximately static between 2004 and 2005.

15. The enhancement courses provide £150 a week (£225 from 2007) for six months to the participants. Many participants have relinquished well paid jobs and have families and significant financial commitments. The courses are only funded from January to June, leaving a gap without support until the start of the ITE courses in September. Participants are not eligible for student loans. The Institute believes that if a loan structure could be made available, the courses would have significantly more appeal to trainees.

16. It is clear from our members that many potential teachers are put off teaching by the thought of teaching biology. They feel that they have a much stronger affiliation with mathematics. The Institute believes that TDA should pilot a physics and mathematics PGCE.

17. It is also clear that the perceptions about issues surrounding workload, status, and discipline are significant deterrents to entering teaching. The Institute believes that government must ensure that they make the working conditions for teachers as attractive as possible.

### *Training*

18. There is a series of structural issues that, cumulatively, has had a chronic negative impact on the recruitment of students to teacher training, and on the effectiveness of teacher training in science subjects, particularly physics.

19. Education departments have a low status within universities in general. One reason is their relatively poor income stream; another is the conflict between producing research papers that contribute to the RAE grades, and spending time on training teachers. As a result, from the very outset, the universities are not keen for PGCE departments to take on any initiatives within teacher training, unless they can be justified on a strictly financial basis. When the Physics Enhancement Project was launched, the TDA only received seven bids for eight tenders. The Institute urges the TDA to work with the Treasury to relieve the inherent conflict between RAE performance and teacher training capacity.

20. We understand that it was in response to the ongoing problems of recruitment of trainees that the TDA raised the amount paid to ITE institutions by £1,000 per annum per head for physics and chemistry trainees from September 2006. However, initial enquiries suggest that many institutions have so far been slow to respond to the extra funding available, by deploying the money into extra marketing, for instance. In some, but not all institutions, there appears to be a substantial disconnection between those who are responsible for the financial administration and the PGCE tutors.

21. Science is a demanding subject in terms of teacher training. The trainee teacher has to ensure that they have the appropriate subject knowledge, much of it unfamiliar, across all three sciences. Additionally, they have to come to terms with the pedagogical issues associated with the three sciences. This requirement is likely to get more demanding as moves towards curricula that develop scientific literacy will require different

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teaching approaches from those aimed at scientists. In addition, science teachers have to develop the repertoire of skills associated with managing practical work in the classroom.

22. The effectiveness of courses themselves is also limited by factors external to ITE institutions. PGCE tutors have privately admitted that, due to the lack of physics specialists in schools and the poor recognition that schools based mentors receive, they find it increasingly difficult to place trainees in satisfactory science departments. The Institute believes that the TDA must work to increase the quality and quantity of school based placements available to physics and chemistry PGCE trainees.

23. It is our impression that, for the reasons stated above, the year-long PGCE course is not adequate to develop the necessary habits and skills that are required to sustain a science teacher through their career. If professional development were better established, then this might be less of an issue.

#### *Professional Development*

24. The Institute supports moves to raise the profile of professional development for all teachers. We believe that there needs to be a culture change within the teaching profession, where all teachers feel obliged to engage in professional development.

25. It is clear that there is a substantial need to support non-specialists teaching physics. The Institute undertook a comparison between the contents of science-related degrees and the contents of physics courses in schools. The aim was not to cast doubt on the competence of existing or future physics teachers who do not have a physics degree, but rather to try to identify areas where they may be in need of additional support.

26. The study concluded that:

- only people with physics degrees have a sufficient knowledge base to teach A-level physics without significant subject-based support;
- graduates in mechanical engineering, electrical engineering, aeronautics, materials and chemistry will have sufficient knowledge of physics to enable them to cope with a significant proportion of the physics curriculum, but they will have large gaps in their knowledge and should be given access to significant professional development;
- graduates in civil engineering, chemical engineering, Earth science and applied mathematics will have encountered only a limited part of the physics curriculum and will need significant professional development to enable them to cope;
- at GCSE, graduates of engineering or sciences other than physics or will have significant gaps in their knowledge and understanding (although these would be mitigated if they have studied A-level physics).

27. The Institute has developed a training programme that is based around a set of five interactive CDs to support the teaching of physics at KS3. The five CDs cover: forces; light and sound; electricity and magnetism; energy; and space. They balance the consolidation of existing good practice amongst teachers with the development of new teaching tools. We have been working with the Science Learning Centres and others to provide training based around this resource. However, despite very positive feedback from teachers who have attended the training, the uptake of courses has been very disappointing.

28. In an attempt to address some of the problems in persuading teachers to attend out of school professional development, the Institute has set up a Physics Teachers Network to try to encourage the sharing and developing of ideas for teaching physics. The Network is run by co-ordinators, who are mostly practising teachers. The co-ordinators organise and co-ordinate local group activities and training much of it run as twilight sessions at local venues.

29. The government must work with teachers to motivate and encourage them to engage in professional development. What is now required is either a very effective carrot or an equally effective stick to ensure that the people most in need of this support actually take advantage of professional development. It is our experience, and that of comparable organisations in cognate disciplines, that the teachers most in need of help are the slowest coming forward. In providing this incentive the government needs to tackle the reluctance of head teachers to release staff for subject-specific INSET. Further government intervention is absolutely necessary if we are to make a significant difference to the skills, knowledge and confidence of teachers of physics.

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## THE CURRICULUM

30. We believe that the move towards science as a subject rather than separate sciences has had a very profound effect on the recruitment and retention of physics teachers. It has also had a significant effect on the management of science within schools, where some head teachers do not appear to recognise the breadth that is covered by science and the consequent challenge for teachers, support staff and students.

31. Government and its agencies do not seem to be aware of the workload issues that arise from changes to the science curriculum. We are very concerned that, in 2008, teachers in 11–18 schools will be faced with changes to KS3, the third year of a significantly altered GCSE and new A-levels. These changes appear to be taking place in a piecemeal fashion with too little time for serious discussion and active engagement of teachers about what concepts are best taught where.

32. Regulatory authorities, such as QCA, must consider how concepts and skills are developed at different stages of physics education. They should also ensure that the curriculum provides students and teachers with a coherent and accurate view of what physics is; in particular, there should be an appropriate balance between the teaching and assessment of skills and theories. We are also concerned that, perhaps as a result of frequent changes, a number of errors and misconceptions seem to be creeping into specifications and exam papers.

33. The Institute believes that teachers are not engaging positively in curriculum change. This problem was highlighted at a recent seminar, organised by the Institute and the Royal Society, for mathematics and physics teachers. A key issue reported by the teachers was that the current context in the school—accountability through exam results, a lack of time, and the compartmentalisation of the curriculum—has led to a situation where teachers are in a sense de-professionalized. They do not have the time, inclination or support to innovate and they teach for exam results rather than for learning.

34. There is something of a vicious circle here—curriculum change follows inspection and research evidence on the paucity of some teaching. The change is imposed on teachers adding to their sense of a loss of control and professionalism. It is not clear how this circle is broken but the enthusiasm of the teachers at the seminar to initiate change in their own schools suggests that the answer may already be in schools. It was interesting that teachers in independent schools felt less constrained and yet, if anything, are more accountable for the exam results of their students.

35. The Institute recognises that assessment serves a number of purposes, including checking the performance of individual students and their schools as well as informing the teaching and learning process. Currently, much of the teaching and learning that takes place is driven by summative assessment which does little to improve teaching and learning. The obsession with exams results in rote teaching, which is uninspiring, and does not encourage the development of understanding.

36. The Institute would like to see an assessment regime that is valid, effective, and benign in its impact on teaching and learning, whilst commanding public confidence. In addition, the Institute would support moves to reduce the assessment load that is placed upon students and teachers.

37. The GCSE Science specifications that will be taught from September 2006 are intended to satisfy two aims for science education:

- ensuring that all students are equipped with the basic scientific literacy required for people who will have to make decisions in response to advances in science and technology;
- ensuring the supply of scientist and engineers to produce the advances in science and technology.

38. We regard the first as vital, but it is too early to say much about whether this aim will be met. However, the lack of financial support and professional development for science departments does not bode well. In this response, we will confine ourselves to the discussion of how effectively this second aim has been met and what measures might be taken to improve the supply of scientists and engineers.

## PARTICIPATION IN PHYSICS

### *Universities*

39. Before considering subject choice at 16, it is perhaps worth examining the situation at undergraduate level. During the period 1997 to 2004, a time of rapid expansion in HE, the number of physics students appears to have remained stable. In sharp contrast, some other undergraduate subjects have increased dramatically over this period. The number of students taking undergraduate chemistry and materials science has continued to fall, with the latter rapidly disappearing as an independent undergraduate discipline. More popular physics

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departments have been able to compensate for the loss of income by increasing their intake of undergraduate students. This has been at the expense of the smaller departments, which have not been able to attract sufficient students and have subsequently closed.

40. It is also interesting to note that, of the total number of first year full-time, UK domiciled, first degree students attending physics courses at university, only one in five are female, which is similar to the proportion of females taking physics A-levels (see figure 2). This indicates that whatever discourages girls from doing physics has already taken place before the choice of A-level is made.

41. Table 2 shows that physics is not recruiting equally from all backgrounds. It is not clear if this effect reflects the cultural values of the different groups (if these exist) or the differences in the schools. The fact that both physics and mathematics A-levels are entry requirements may also be a factor.

**Table 2**

ACCEPTANCES TO DEGREE 1996–2000 BY SUBJECT AND SOCIAL CLASS BASED ON PARENTAL OCCUPATION

	<i>Physics</i>		<i>Biology</i>		<i>Chemistry</i>		<i>STEM</i>		<i>Total</i>	
I Professional	2,594	19.13%	4,341	16.72%	3,046	16.28%	36,610	16.40%	195,153	13.17%
II Intermediate	5,414	39.93%	10,426	40.15%	7,140	38.17%	86,717	38.84%	571,273	38.56%
IIIM Skilled Manual	1,966	14.50%	3,744	14.42%	2,999	16.03%	33,255	14.90%	218,819	14.77%
IIIN Skilled non-Manual	1,492	11.00%	2,855	11.00%	2,070	11.07%	24,403	10.93%	178,308	12.03%
IV Partly Skilled	955	7.04%	1,910	7.36%	1,489	7.96%	16,897	7.57%	113,300	7.65%
V Unskilled	191	1.41%	409	1.58%	398	2.13%	3,605	1.61%	26,922	1.82%
X Unknown	948	6.99%	2,280	8.78%	1,563	8.36%	21,754	9.74%	177,835	12.00%
<b>Grand Total</b>	<b>13,560</b>		<b>25,965</b>		<b>18,705</b>		<b>223,241</b>		<b>1,481,610</b>	

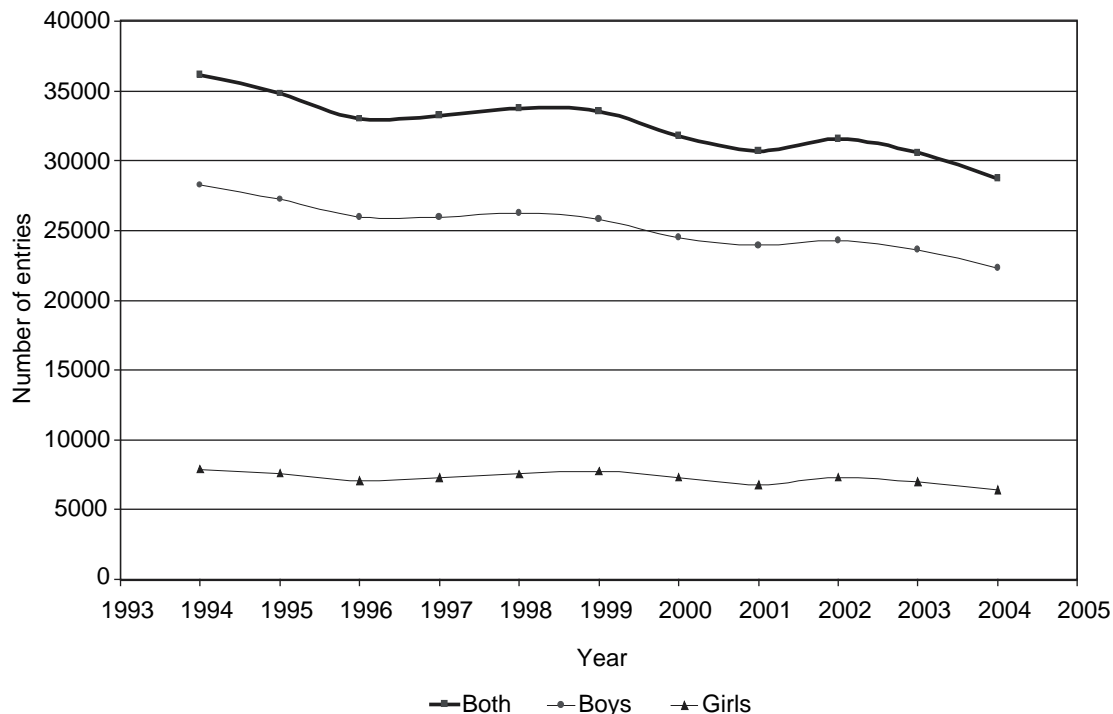
*Trends in A-level physics and undergraduate recruitment*

42. Since the early 1990s, there has been a decline in the popularity of physics as a subject in schools. Over the last decade or so, the number of pupils taking A-level physics has fallen by around 20 per cent (see figure 2) whereas the total number of students taking all A-levels has remained roughly the same. Similar falls have occurred in chemistry and mathematics. Part of the reason for these decreases is undoubtedly due to pupils choosing alternative A-level subjects.

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**Figure 2**

THE NUMBER OF ENTRIES TO A-LEVEL EXAMINATIONS IN PHYSICS 1994–2004.  
(SOURCE: AQA)



43. We believe that teacher quality has the greatest effect on students' attitudes towards science and their choice of the sciences post-16. No amount of enhancement activity can compensate for a poor experience in school. This view is supported by the evidence, which shows relatively poor take-up of physics in schools where pupils are least likely to have received specialist teaching.

#### *Girls and ethnic minorities in physics*

44. However, even in schools where there is specialist teaching, more might be done to engage learners in science and convince them that they have a future in science. Figure 2 shows the huge difference in the uptake of physics by boys and girls at the age of 16. In 2005, there were 28,119 UK candidates for A-level physics making it the 12th most popular subject; 21,922 of these candidates were male making it the 6th most popular subject and 6,197 females, the 19th most popular. The Institute has commissioned research to explore why girls are under-represented in post-16 physics.

45. The Ofsted database was used to analyse by gender the 2002 AS physics entry and 2003 A-level entry in a random sample of 1,500 maintained secondary schools. Schools were ranked according to the proportion of the female cohort entered for physics and in mixed schools the difference between the male and female entry in 2003.

46. Only 80 schools from this sample recruited 10 per cent or more of their post-16 girl cohort to take A-level physics in 2003. Of these schools, 44 were girls' schools of which 36 select by attainment; 10 had more than 20 per cent of their cohort taking physics. Between them, these 80 schools, 5 per cent of the sample, accounted for 675 out of a total of 3,025 girls studying A-level physics; nearly a quarter of the total number of A-level physics entries.

47. The following issues emerged:

- The most commonly cited reason for the lack of participation in physics A-level is the perceived lack of relevance of the subject, either to the students' aspirations or to the world at large.



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- The experience of physics in the classroom is the primary factor in determining whether students, particularly females, carry on with the subject. Girls are much more likely than boys to be deterred by poor and uninspiring teachers. The general ethos of the school and its attitude to science are also important factors.
- A large number of students, particularly girls, are deterred from further study in physics by the feeling that the subject, with its associated mathematical content, is too difficult and “not for them”, even when they are perfectly well qualified to continue.
- Specific interventions targeting girls separately to encourage them into science have largely been ineffective.

48. The Institute worked with the Royal Society of Chemistry to look at the participation of ethnic groups in physics and chemistry. The research shows that a number of ethnic minority groups are under-represented although some are over-represented at A-level and beyond. The under-representation seems to start at GCSE with a number of ethnic groups under-performing and consequently being unable to progress to further study in the sciences. The situation is obviously very complex and so it is not entirely clear what causes this under-representation—it may be that the causes are the same as those that produce under-representation from the lower socio-economic groups.

## OTHER FACTORS

### *Difficulty*

49. The perception that physics is a difficult subject contributes to a lower uptake at school. Anecdotally, this effect is not just the result of students avoiding the more difficult subjects but also schools actively discouraging students from taking subjects that could weaken their league table position. However, the modal grade for physics is A, indicating that those who do take A-level physics do well at it. Similar remarks also apply to mathematics A-level.

### *Practical Work*

50. Another issue that may be putting students off continuing with science post-16 is the quantity and quality of practical work taking place in schools. The Institute believes that practical work plays a vital role in physics education. As well as developing skills that are required for further study and employment in physics, practical work can help students to understand concepts; it can also be a powerful motivational tool. The Practical Physics website has been developed by the Institute and the Nuffield Curriculum Centre to support practical work in physics in the 11–17 age range. The website will help teachers share their skills and experience of making experiments work in the classroom.

51. The Institute believes that the following are barriers to effective practical work in physics:

- too many students in practical classes and the associated behavioural problems;
- inappropriate assessment of practical work;
- insufficient funding being devolved to science departments;
- under resourced and old fashioned laboratories in schools and colleges; and
- teachers who are not confident teaching physics.

52. A recent report, *Estimating the Relationship between School Resources and Pupil Attainment at GCSE* produced by the Institute of Education on behalf of the DfES found that:

- higher levels of per pupils expenditure were associated with significantly higher levels of attainments at GCSE . . . in science; and
- lower pupil teacher ratios were associated with significantly better overall GCSE performance . . . in Science GCSE specifically.

This suggests that if the government is committed to increasing participation by increasing attainment it should be looking at the funding received by science departments in schools and the size of science classes.

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### *Careers Advice*

53. The Institute is very concerned that students are not being given accurate careers advice at a sufficiently early age to allow them to make informed choices. Currently, careers advice tends to be reactive and does not give students a full picture of the consequences of subject choices. This is exacerbated by recent changes to the structuring of the careers service where insufficient attention has been paid to the skills and knowledge of those required to give useful and accurate careers advice.

54. In 2000, NIECEC produced a report *Choosing Science at 16*. The report examined the factors influencing pupils' choices at 16 and found:

- Teachers often do not see themselves as a source of information or advice about careers in science and technology—not feeling able to keep up with careers information, and instead leaving it to the careers advisers, with whom they had very little direct interaction. The highly content driven science curriculum gave no time for wider-ranging discussion about current science issues and careers.
- There is insufficient co-ordination between advisers and science departments on activities designed to enhance pupils' awareness of opportunities in science-related areas, such as parents' evenings, conventions/industry days and joint training days for careers advisers and teachers.
- The majority of the careers advisers surveyed were graduates with a humanities or social science background. Only one in 10 had science degrees, with none possessing physical science backgrounds.

The DfES does not seem to have taken any steps to address these issues.

55. A recent report commissioned by the Institute and the Royal Society of Chemistry, *The Economic Benefits of Higher Education Qualifications*, reported that the return of public investment for physics and chemistry graduates, and their earning potential was significantly greater than for a number of other, more popular subjects. Worryingly, this seems to have come as surprise to many of those involved in advising young people about careers.

56. It is imperative that an educated student market deciding what degrees to undertake is created. A significant problem facing science, and particularly physics, is that students are making ill-informed decisions about their careers at the age of 15. Students at this age, irrespective of whether they are girls, from ethnic minorities etc, are not well-educated consumers. Teachers, parents, careers advisors should be in a position to highlight the benefits and the wide variety of career options that are available from science.

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## **Memorandum by the Royal Society**

### 1. INTRODUCTION

1.1 The Royal Society is an independent academy promoting the natural and applied sciences. Founded in 1660, the Society has three roles: as the UK academy of science, as a learned society and as a funding agency. Working across the whole range of science, technology, engineering and mathematics disciplines, one of the Society's main aims is to support science communication and education. Its education programme covers formal education in science and mathematics from Primary level through to Higher Education. As with all Royal Society programmes, the education programme upholds the values of excellence in science, leadership, independence, equality of opportunity, inclusiveness and scrupulous attention to evidence. The Society believes very strongly that science education must both prepare all young people as citizens of an increasingly science-focused world and maintain the supply of talented and enthusiastic individuals who will be the scientists, engineers and technicians of the future.

1.2 The Society is pleased to respond to the Committee's inquiry into science teaching, particularly as it is in the process of expanding its education programme and increasing its readiness to tackle the key issues raised by the Committee. One of our core principles is to proceed in partnership, and build on existing knowledge and strengths within the science education community. The Society anticipates that the Committee will be receiving many submissions from other organisations in the science and education communities with information regarding specific issues concerning science teaching in schools. Therefore the Society intends not to duplicate this evidence but offer some key messages regarding the overall situation that are crucial if these specific issues are to be successfully addressed.

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## 2. SUMMARY OF KEY MESSAGES

2.1 *Next Steps*. Government recently set some very challenging ambitions for science and mathematics education in its Next Steps document<sup>5</sup> for increasing school students' attainment in science, the number of young people taking A levels in physics, chemistry and mathematics, and the recruitment, retraining and retention of science teachers. These ambitions are intended to secure a strong supply of scientists and technologists to support future UK research and development and are therefore welcomed by the Society. However, concerns have been expressed that the strong thrust of the ambitions towards ensuring a healthy supply of future scientists may not favour the equally important goal of scientific literacy for all, and indeed may impede it given new initiatives that have not yet had time to bed down. Questions have also been raised regarding the assumptions of cause and effect behind the move to triple science GCSE entitlement, the strain on schools to offer this entitlement (at present, only one third of eligible schools enter any candidates for separate science GCSEs leaving an additional 2,500 schools that are being asked to ensure that their students who achieve Level 6 at Key Stage 3 have access to this option from 2008) and the underestimation of turnover and loss of science teachers when calculating numbers of additional specialist teachers needed. The Society strongly recommends that the DfES engages with those collecting data regarding science teachers, particularly teacher vacancies, to ensure it is fully informed of the extent of the challenges ahead.

2.2 *Responsibility and reform*. Government must ensure that the current pace of reform impacting on school science education does not contradict efforts to increase the professionalism of science teachers and contribute to the worrying numbers leaving the profession. Government must also allocate adequate funding and support for change, and be explicit about its distribution to schools. While change is often necessary, there are many excellent science teachers in our schools and colleges and we do encourage those contemplating change to build on and celebrate the good practice that already exists, and to ensure that reforms do not inhibit that good practice.

2.3 *Evidence, monitoring and evaluation*. New initiatives must be supported by good evidence, drawn from international comparisons where appropriate and possible, and show how they will be properly embedded within the Government's overall strategy for science and mathematics education. The links between research, policy-making and their interface with classroom practice must be strengthened. The Society recommends that the Government make annual reports on progress towards the ambitions in the Next Steps document, either on the March anniversary of the publication of the document, or the July anniversary of the original report on "Science and innovation investment framework 2004–14".

2.4 *Partnerships*. The Government has already highlighted the wealth of initiatives supporting STEM education through its STEM review, and is in the process of implementing new, more effective structures for delivery, governance and funding of STEM support activities at national, regional and local levels. The Society looks forward to taking an appropriate role within these structures and fully supports a new framework of co-ordination for such initiatives. The science and education communities (and those that fund and support them) are passionate, committed and knowledgeable about supporting science teaching in schools. As one of these organisations, the Royal Society feels that one of its most important roles at this time is to help Government interact with these communities in the most effective way, capitalising on their combined strengths for the benefit of young people.

2.5 *Teachers, technicians and teaching assistants*. The Government should seriously consider the need for a national strategy which will ensure that none of our secondary schools are without a specialist teacher in each of the sciences. Teachers, technicians and teaching assistants deserve to be valued highly and given a proper career structure: continuing professional development (CPD) for all three groups must become a statutory entitlement acknowledged by a fully funded and integrated system of professional recognition. One step towards this should include earmarking to subject-specific professional development at least one day of the existing annual teacher INSET entitlement. The implementation of policy such as this supporting science and mathematics education depends very strongly on the enthusiasm and skills of headteachers and their leadership teams.

2.6 *Curriculum and assessment*. Many scientists are extremely supportive of reforming the science curriculum to make it more relevant to young people and more revealing about science. The Society hopes that the new suite of science GCSEs—of which Twenty First Century Science is just one—will give young people a better understanding of the true dynamism of science and how it is undertaken as well as inspiring students about science and encouraging more of them to choose one or more sciences after the age of 16. But creating flexibility in the curriculum only becomes a positive force in science education if science teachers have the time

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<sup>5</sup> *Science and Innovation Investment Framework 2004–14: Next Steps* HM Treasury/DTI/DfES/Department of Health (2006).

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and resources to use that flexibility to better meet the needs of their students. The continued dominance of a high-stakes system of external testing throughout Primary and Secondary education makes innovation in assessment for learning difficult to implement, and continues to drive a culture of “teaching to the test”—seen by a range of stakeholders as one of the most significant afflictions of science education today. The Society recommends that the DfES and QCA ensure that assessment for learning (ie formative assessment) is embedded in teaching and that new summative assessment, whether in the national curriculum or post-16, rewards excellent teaching in science.

2.7 *Practical work.* Open-ended investigative work, particularly of a long-term nature, should be promoted as the most appropriate way of engendering experimental and investigative skills at all ages. But the impact investigative work has on young people, as in all things, is dependent on the competence and confidence of the science teacher, adequate resourcing and good technician support.

2.8 *Disadvantage and diversity.* Evidence is available regarding unacceptable variation in student attainment and science teacher availability across types of student (particularly social class but also ethnicity and, to a lesser extent, gender), school and location. Reducing these gaps must be a fundamental aim of national education policy.

### 3. THE CURRENT SITUATION—OVERALL ISSUES

3.1 The Committee’s inquiry comes at a crucial time for science education. The Government has been pursuing an active programme of change and reform affecting science education, for example: reducing the statutory requirements for science at Key Stage 4 and introducing a new strand of science GCSEs in 2006; reviews of both A levels and the Key Stage 3 curriculum; the Primary and Secondary National Strategies; the specialist schools and academies programme; and the national network of Science Learning Centres.

3.2 In addition, Government recently set some very challenging ambitions for science and mathematics education in its Next Steps document<sup>6</sup> for increasing school students’ attainment in science, the number of young people taking A levels in physics, chemistry and mathematics, and the recruitment, retraining and retention of science teachers. These ambitions are intended to secure a strong supply of scientists and technologists to support future UK research and development and are therefore welcomed by the Society. However, concerns have been expressed that the strong thrust of the ambitions towards ensuring a healthy supply of future scientists may not favour the equally important goal of scientific literacy for all, and indeed may impede it given that new initiatives have not yet had time to bed down. Questions were also raised regarding the assumptions of cause and effect behind the move to separate subject GCSE entitlement, the strain on schools to offer this entitlement (at present, only one third of eligible schools enter any candidates for separate science GCSEs leaving an additional 2,500 schools that are being asked to ensure that their students who achieve Level 6 at Key Stage 3 have access to this option from 2008) and the underestimation of turnover and loss of science teachers when calculating numbers of additional specialist teachers needed. The Society strongly recommends that the DfES engage with those collecting data regarding science teachers, particularly teacher vacancies, to ensure it is fully informed of the extent of the challenges ahead. The Society also notes additional evidence from the last annual report from Ofsted which states that, “The number of teaching vacancies in science is higher than in any other subject. This is having an adverse effect on teaching and is limiting improvements in the subject”<sup>7</sup>.

3.3 Government must ensure that the current pace of reform impacting on science education does not contradict efforts to increase the professionalism of science teachers and contribute to the worrying numbers leaving the profession. Policy-makers must take due account of the effects on science teachers by properly consulting with them and their representatives before policies are finalised. Government must also allocate adequate funding and support for change, and be explicit in its distribution to schools. The Society has been disappointed with the level and co-ordination of support for the new science GCSEs being introduced in September 2006, and would like to know precisely how the £32 million allocated in support of the Next Steps ambitions is going to be spent. While change is often necessary, there are many excellent science teachers in our schools and colleges and we do encourage those contemplating change to build on and celebrate the good practice that already exists, and to ensure that reforms do not inhibit that good practice.

3.4 New initiatives must be supported by good evidence, drawn from international comparisons where appropriate and possible, and show how they will be properly embedded within the Government’s overall strategy for science and mathematics education. The Society is concerned that the success of the national

<sup>6</sup> *Science and Innovation Investment Framework 2004–14: Next Steps* HM Treasury/DTI/DfES/Department of Health (2006).

<sup>7</sup> *Science in Secondary Schools*: HMI/Office for Standards in Education (2004).

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network of Science Learning Centres—a very valuable contribution to the professional development of science teachers and technicians from the DfES and the Wellcome Trust—is dependent on institutional change within schools that is not being supported by change in relevant areas of education policy.

3.5 Further, the links between research, policy-making and their interface with classroom practice must be strengthened. The Society notes that the science and maths specialist teams within QCA are being dispersed, and the subject-specific annual reports on teaching and learning undertaken by Ofsted have been diminished, which appears to be at odds with Government's strategic priorities in these subjects. The Society hopes that the DfES is retaining the quality of staff and outputs in these core areas through other means.

3.6 The Government has already highlighted the wealth of initiatives supporting STEM education through its STEM review, and is in the process of implementing new, more effective structures for delivery, governance and funding of STEM support activities at national, regional and local levels. The Society looks forward to taking an appropriate role within these structures and fully supports a new framework of co-ordination for such initiatives. It is important to recognise that new policies, initiatives and activities, whether from the Government, professional bodies, charities or the private sector must arise from evidence of need, be accurately targeted at those groups who have most to benefit, and commit to an appropriate programme of monitoring and evaluation, the results of which should be made available to inform others. The Society is disappointed that evaluations of major initiatives like Science Year/Planet Science and the Science and Engineering Ambassadors scheme have not been made widely available. The Society recommends that the Government make annual reports on progress towards the ambitions in the Next Steps document, either on the March anniversary of the publication of the document, or the July anniversary of the original report on "Science and innovation investment framework 2004–14".

3.7 The Committee will be aware that the science and education communities (and those that fund and support them) are passionate, committed and knowledgeable about supporting science teaching in schools. The Royal Society numbers amongst them, but also feels that one of its most important roles at this time is to help Government interact with these communities in the most effective way, capitalising on their combined strengths for the benefit of young people. The Society recently commissioned PricewaterhouseCoopers to explore new mechanisms to support more effective engagement. The results of this study will be available in the summer.

#### 4. SPECIFIC ISSUES

While not wishing to repeat the information given by other organisations, the Society would like to highlight a number of key concerns relevant to the issues raised by the Committee in its call for evidence.

##### 4.1 *Attracting science teachers*

4.1.1 Evidence suggests that teachers represent the largest single source of variance in learning other than the students themselves. According to a recent report from the National Foundation for Educational Research (NFER)<sup>8</sup>, 44 per cent of science teachers held a specialism in biology in contrast to 25 per cent with a specialism in chemistry and 20 per cent with a specialism in physics. In mathematics 24 per cent of teachers were either non-specialists—meaning that they did not have a degree in maths or associated subject or had not studied the subject as part of their initial teacher training—or were predominantly teachers of other subjects. If we are to halt the decline of numbers of students studying maths and the sciences, physics and chemistry in particular, at A-level and beyond, then we need teachers who are both enthused and knowledgeable in the subjects that they are required to teach. The NFER report revealed a disappointing number of teachers with a specialism in the subjects that need it most. The report also highlighted that teachers with a specialism in physics and chemistry are less likely to work in schools with lower than average GCSE results and a higher than average percentage of students eligible for free school meals—meaning that the disadvantaged are more disadvantaged still. The Society would like to know how the Government is responding to the NFER report and how it will keep track of its own progress by the regular collection of detailed data on the qualifications and deployment of teachers of mathematics and the sciences. The effects of market forces will continue to work against schools that struggle with recruitment because of available resources and challenging circumstances. While statistics of recent years show successes in recruitment to initial teacher training, these are offset by the attrition from the profession caused by numbers failing to achieve qualified teacher status and by the number of teachers leaving the profession (particularly in their first five years) or retiring. At a recent Royal Society conference

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<sup>8</sup> *Mathematics and Science in Secondary Schools: The Deployment of Teachers and Support Staff to Deliver the Curriculum*, National Foundation for Educational Research (2006).

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on increasing the uptake of science A levels<sup>9</sup>, we heard evidence that with retirements among science teachers over the next 10 years expected to be at least as high as the average number of retirements among all secondary school teachers (estimated to be between 33 per cent and 40 per cent), government will have to invest heavily in professional development and/or alternative sources of recruitment for subject specialists if shortfalls against its targets persist.

4.1.2 In light of these findings the Government should seriously consider the need for a national strategy which will ensure that none of our secondary schools are without a specialist teacher in each of the three school sciences. This is not just a question of recruiting or retraining specialist science teachers, but how they are deployed and retained within and between schools. The Society has been pleased to provide a grant to the Centre for Science Education at Sheffield Hallam University to explore successful strategies used by schools to overcome retention problems in their science departments. The final report will be available by the end of the summer. We hope the Government will support an increased emphasis on science teacher retention, and consider setting targets beyond recruitment to ITT in order to monitor their performance in this area.

## 4.2 *Teaching science*

### 4.2.1 Professional development

Teachers, technicians and teaching assistants deserve to be valued highly and given a proper career structure: continuing professional development (CPD) for all three groups must become a statutory entitlement acknowledged by a fully funded and integrated system of professional recognition. One step towards this should include earmarking to subject-specific professional development at least one day of the existing annual teacher INSET entitlement. A survey<sup>10</sup> undertaken by the ASE and the Royal Society provided a unique database of information on the roles, responsibilities, working conditions and opinions of laboratory technicians working in secondary schools and colleges. Progress has been made against the recommendations<sup>11</sup> set out in the follow-up report which mapped out ways forward for improving the status and recognition of science technicians working in schools and colleges, but the ASE reports that there are still several fundamental issues that need to be addressed relating to: the implementation of an improved career structure; opportunities for technicians to gain recognised qualifications which ASE has taken forward in partnership with the Design and Technology Association through funding from the Gatsby Charitable Foundation; and funding of technicians to attend courses and register for qualifications.

### 4.2.2 The curriculum

Many scientists are extremely supportive of reforming the science curriculum to make it more relevant to young people and more revealing about science. Science learning must be, at all levels, about the process of discovery as well as scientific facts. The Society hopes that the new suite of science GCSEs—of which Twenty First Century Science is just one—will give young people a better understanding of the true dynamism of science and how it is undertaken as well as inspiring students about science and encouraging more of them to choose one or more sciences after the age of 16. In reforming the science curriculum, the Government has recognised that we need to reverse the trend of so many young people dropping science as soon as they can, as well as better prepare them to face the many opportunities and dilemmas that science and technology continue to present in an increasingly complex world.

However, creating flexibility in the curriculum only becomes a positive force in science education if science teachers have the time and resources to use that flexibility to better meet the needs of their students. In terms of progress in both the curriculum and assessment, the Tomlinson inquiry made many recommendations that received wide support from the science education community, yet the Government's response has been unclear. The Society suggests it is time for the Government to publicly revisit the Tomlinson recommendations and gather the views of the community regarding a long-term vision for science education.

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<sup>9</sup> *Increasing uptake of science post-16*, Report of a Royal Society conference held on Friday 10 March 2006 at the Royal Society, London (in press).

<sup>10</sup> *Survey of science technicians in schools and colleges*, ASE & Royal Society (2001).

<sup>11</sup> *Supporting success: science technicians in schools and colleges*, ASE & Royal Society (2002).

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#### 4.2.3 Assessment

The way in which learning is assessed has a determining influence upon student attitudes towards, and interest in, science at school and college. Two years ago the Royal Society published a report on the assessment of science learning 14–19 based on work by King’s College London. We warned that school science examinations were failing to prepare students for their future careers and studies and were examined on too narrow a range of skills, such as rote learning and mastering standardised and predictable experiments, to the neglect of those demanded by employers and universities. The continued dominance of a high-stakes system of external testing throughout Primary and Secondary education makes innovation in assessment for learning difficult to implement, and continues to drive a culture of “teaching to the test”—seen by a range of stakeholders as one of the most significant afflictions of UK science education today. The Society recommends that the DfES and QCA ensure that assessment for learning (ie formative assessment) is embedded in teaching and that new summative assessment, whether in the national curriculum or post-16, rewards excellent teaching in science.

#### 4.2.4 Practical work

More has probably been written about practical science<sup>12</sup> than about any other aspect of school science education. This reflects the view that “hands-on” experience in the laboratory or field is a distinctive and fundamental element in learning science. The Royal Society’s Partnership Grants scheme, which funds projects linking Primary and Secondary schools with scientists and engineers, has enabled many good teachers over the years to be creative and inspiring with practical projects involving role models. The Royal Society considers that the skills and knowledge developed through fieldwork can be integral to the purposes of science education: to train experts able to serve science and society through research; to educate all young people in the fundamental processes of scientific investigation; and to prepare citizens of the future for responsible management of their environment. The Society is therefore concerned that the available research data (from small scale studies<sup>13, 14</sup>) suggest that fieldwork is being diminished throughout the education system by a number of pressures on schools, colleges and universities.

Such evidence as exists suggests some cause for concern about the current teaching of practical science in schools. For example, while reports from Ofsted on trends in Primary science have linked high standards of achievement to good use of scientific enquiry, they also caution that: “. . . *scientific enquiry remains the most variable and vulnerable part of the science curriculum. Science is largely taught in relatively short afternoon sessions . . . [and this] . . . seriously constrains teachers’ ability to develop investigative activity. As a result, many investigations have become highly structured and give insufficient freedom for pupils to contribute their own ideas or reflect on outcomes.*”<sup>15</sup> The picture in Secondary schools is similarly mixed: “*Scientific enquiry and investigative practical work in particular remain issues in many schools. The Key Stage 3 strategy has led to significant improvement in Years 7 and 8, but beyond this, much investigation is narrow in range and sharply concentrated on the perceived demands of coursework assessment.*”<sup>16</sup>

Open-ended investigative work, particularly of a long-term nature, should be promoted as the most appropriate way of engendering in students experimental and investigative skills. But the impact such work has on young people, as in all things, depends on the competence and confidence of the science teacher, adequate resourcing and good technician support.

### 4.3 Schools

4.3.1 The Society is very concerned about current variations between institutions in the teaching of science, and the impacts further reforms may have on these gaps. For example, science take-up is strongly skewed at present, with half of all A level entries in science coming from just 18 per cent of schools. Evidence is available regarding unacceptable variation in student attainment and science teacher availability across types of student (particularly social class but also ethnicity and, to a lesser extent, gender), school and location, and reducing these gaps must be a fundamental part of national education policy. This will require an understanding that

<sup>12</sup> “Practical science” is used as shorthand for the full programme of experimental and investigative activities (including fieldwork) conducted as part of science education in schools and colleges.

<sup>13</sup> Barker, S, Slingsby, D and Tilling, S (2002) *Teaching biology outside the classroom. Is it heading for extinction?* Field Studies Council/ British Ecological Society.

<sup>14</sup> Lock, R and Tilling, S (2002) *Ecology fieldwork in 16–19 biology*, School Science Review, **84**(307).

<sup>15</sup> *Science in Primary Schools*: HMI/Office for Standards in Education (2004).

<sup>16</sup> *Science in Secondary Schools*: HMI/Office for Standards in Education (2004).



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to inspire students with different backgrounds, aptitudes, interests and motivations, a diverse range of high-quality teaching strategies and enrichment activities may need to be available in schools.

4.3.2 The Society shares the concerns of other professional bodies, notably the Royal Society of Chemistry, supported by evidence from Ofsted (“Almost one in six schools has unsatisfactory accommodation for science”)<sup>17</sup>, that despite a start, much work needs to be done to bring many school laboratories, and the associated areas, up to a standard that will promote a positive learning experience for science students.

4.3.3 It is important to consider the role of the Primary, Further Education and Higher Education sectors when debating these issues. Despite the complexity, too many policy decisions are made without considering the education system in its entirety. For example: it is widely recognised that science teaching and learning in Primary schools can have a profound effect on how young people subsequently engage with science; almost a quarter of A level entries are from the FE sector; increasing A level entries in Physics, Chemistry and Maths through the Next Steps ambitions may prove wasted in terms of the supply of future scientists if enthused young people are unable to find an appropriate course of study at their chosen university. Over the last 12 months the Society has been working on a project entitled *Science Education and the Economy*. After a pilot phase focussing on undergraduate courses designed for professional scientific careers, we are now launching phase II of the work: *Science Higher Education in 2015 and beyond*. This phase of the project will consider whether the overall STM HE provision in the UK will be fit for purpose by the second half of the next decade.

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#### Memorandum by the Biosciences Federation

The Biosciences Federation (BSF) is a single authority representing the UK’s biological expertise, providing independent opinion to inform public policy and promoting the advancement of the biosciences. The Federation was established in 2002, and is actively working to influence policy and strategy in biology-based research—including funding and the interface with other disciplines—and in school and university teaching. It is also concerned with the translation of research into benefits for society, and about the impact of legislation and regulations on the ability of those working in teaching and research to deliver effectively.

The Federation brings together the strengths of 40 member organisations, including the Institute of Biology which represents 42 additional affiliated societies (see Appendix). This represents a cumulative membership of over 65,000 individuals, covering the full spectrum of biosciences from physiology and neuroscience, biochemistry and microbiology, to ecology, taxonomy and environmental science. The Biosciences Federation is a registered charity (No 1103894).

The Biosciences Federation has recently summarised its views on all stages of the National Curriculum in a report entitled:

**“Enthusing the Next Generation”**  
<http://www.bsf.ac.uk/responses/Enthusing.pdf>

#### SUMMARY

1. There is a need to inspire science graduates to want to teach. Unless students receive information about, or experience of, teaching during their university years they are likely to be uninformed about the profession when they make their career choices. Schemes exist such as the undergraduate ambassador scheme which provides a teaching module that can be embedded into degree programmes. Similarly for postgraduates, there is scope for gaining experience of schools through schemes such as the “Researchers in Residence”.
2. The prospect of science teachers having to teach increasingly outside their own specialism is off-putting to science graduates. This problem could be alleviated by providing training through Continuing Professional Development (CPD) schemes and supportive initiatives offered by many professional bodies and learned societies.
3. Without any informative experiences prior to graduation, a science graduate may dismiss teaching as a career entirely. Perceived knowledge of the current state of teaching is that there is a lack of discipline and support structures in schools, and the occupation is low pay, “high-stress”, high work-load.
4. Science students must be made more aware of incentives such as the “golden hello” and the financial support given during training.

<sup>17</sup> (ibid).

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5. It is critical to improve both the quality of teaching and the enjoyment by the pupils. There is no point in boosting KS3 and GCSE attainment if students still steer away from the sciences at A-level because they are not enthused by them.
6. The sciences are perceived by students to be harder than other subjects. In an increasingly assessment-driven school culture, students may shy away from sciences to subjects that they perceive are more likely to give them a better mark.
7. An increase in the number of students pursuing science A-levels could be achieved by widening the entitlement of students to single science GCSEs rather than the more commonly offered double science.
8. Many school laboratories and equipment are out-dated and present a dull and uninspiring environment for student generations who are very influenced by the “look” of things.
9. Whilst the Federation welcomes the new more flexible curriculum at GCSE level, it should be noted that practical work should not be a case of “going through the motions” instead of designing and carrying out real experiments.
10. Links between universities and schools could be better coordinated in order to enhance pupils’ practical experience. However, this must be a recognised and valued activity of university staff and students.

#### *General comments*

11. The BSF is extremely concerned about the sustainable throughput of bioscientists in the UK from schools into university and the wider scientific community. This response brings together their views on the state of science teaching in schools and how it is affecting this throughput.
12. The problems associated with the decline in the number of A-level students choosing to enter the physical sciences are of great concern to members of the Biosciences Federation as the effects of this are already being felt across the sectors. Many innovative entrepreneurial endeavours on which the wealth of the country will rest in the future arise from scientific research and its spin-out companies. As the supply of specialist physical science teachers declines, the pressure on Biology teachers to cover these subjects will further exacerbate the current problem, leading to a decline in the quality of science teaching and an even further reduction in the numbers of students pursuing A-level, and thus Higher Education, science.
13. It should be noted that, although the future of Biology is currently perceived to be less threatened than the Physical Sciences, particular sub-sets of Biology such as Plant Sciences, Microbiology and Taxonomy are becoming less and less popular at HE, with student increases in subjects such as Psychology, Forensic Science and Sport Science masking this decline.
14. Unless a meaningful and fundamental approach is taken, rather than a patch-up approach, scientific research will be severely threatened in the UK in the future. Currently, the problem is being tackled using piece-meal solutions such as *ad hoc* initiatives to inspire young people about science. There is a need for joined-up thinking and a solid foundation and infrastructure which supports and nurtures excellent science teaching and embeds inspirational and enthusing approaches into the day-to-day timetabling so that there is increased throughput of students into universities and on to research.

#### *Attracting science teachers*

15. Under the present national curriculum, all teachers (whatever their specialism) are often required to teach across all 3 sciences (biology, chemistry and physics) up to Key Stage 4 (GCSE) level. This may not only deter science graduates from choosing to teach, it also means a reduction in the quality of non-specialised teaching which in turn deters students from further study and so they are less likely to take up a science subject at A-level. A recent analysis by the Department for Education and Skills (DfES) based on OfSTED inspection data demonstrates a high correlation between pupil achievement and match of science teacher specialism to the curriculum.
16. Feedback from existing teachers in all subject areas shows that lack of discipline in schools is driving experienced teachers from the profession, and that teachers urgently need strong official back up for their work. There is a danger that accounts of these negative experiences in the media may deter more graduates from entering the profession.

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17. “Golden Hellos” provide incentives to graduates to enter teacher training. Evidence from the DfES shows that at the present time, those choosing to undertake a Postgraduate Certificate in Education (PGCE) are awarded a £7,000 bursary for training in a maths or science subject, and a further £4,000 “Golden Hello” if they continue to train in and go on to teach maths, science, technology or modern languages in a maintained school, or non-maintained special school in England (from September 2005). These incentives are due to be increased further from September 2006 for students beginning their PGCE training, with maths and science PGCE students receiving a £9,000 training bursary followed by a £5,000 “Golden Hello” on completing their induction.

### *Teaching science*

18. The reduction in practical work is causing a significant impediment to inspiring the next generation of scientists and equipping students for a research career. Experience has shown that school students that attended summer schools at universities enjoyed hands-on practical work and that it enthused them. Being able to offer a wide range of practicals in the sciences would make a huge difference in student attitude towards the subject, but few schools seem able to offer this now, making for mundane practicals and uninspired students.

19. Newly qualified science teachers are entering the profession ill-prepared to deliver lessons with practical work or field experiences as they themselves are not receiving the training in the delivery of these important aspects of science teaching. Practical work and especially fieldwork is increasingly seen as the province of older, more experienced teachers.

20. It is important for science to be made exciting and its relevance to everyday life made clear to children at an early age (including potential career opportunities). The decrease in practical classes in schools due to cost, health and safety considerations, and bureaucratic pressure on teachers and university professionals alike, must be addressed.

21. Space needs to be included in the timetable so that teachers have scope to enthuse their pupils. The “Spiral Curriculum”—constant repetition of the same topics throughout the Key Stages and at A-level—leaves students (and teachers) uninspired and lacking in enthusiasm and motivation towards science. With so much novel research in the world it would seem a missed opportunity not to provide teachers with a suitable mechanism whereby this can be incorporated into lessons as a tool for motivating students.

22. The new schemes implemented at Key Stage 4 go some way towards stimulating enthusiasm for science in young people but many teachers feel this has been introduced too quickly. Many schools are opting for the more conventional approaches and therefore there has been little change in pupils’ attitudes.

23. The effectiveness of teacher training in the science subjects could be improved by extending training into completing mandatory Continuing Professional Development (CPD) annually through schemes to ensure that teachers’ knowledge and understanding of the curriculum stays up-to-date and that their teaching skills are regularly developed, including their ability to teach outside their specialist subject. The Federation believes that professional scientists could be directly involved in the postgraduate training of secondary school science teachers via a mentoring programme and that trainee teachers should have a solid grasp of practical science as well as the theory of education.

24. The adequacy of professional support for science teachers is a concern, although steps are being taken to move this forward and provide more support via Science Learning Centres around the country. It is important to recognise that more money needs to be steered towards this important factor in order to retain teachers.

25. CPD opportunities need to be advertised more effectively as many schools are unaware of them. In addition, teachers need to have more scope to be released to undertake CPD training courses.

26. Co-ordinated university-school outreach schemes to bring science graduates and academics into schools (such as mentoring schemes, Researchers in Residence and the science ambassadors scheme). The Federation supports the overall philosophy of the STEM mapping project and will seek to share best practice between its Member Organisations to consolidate its expertise and take a coordinated approach to its activities.

27. Staff and students in universities who help to enthuse pupils in schools and colleges must be acknowledged and encouraged within Higher Education. Currently, it is not recognised as a “worthwhile” activity within the RAE Framework and can even count against an academic and other research staff and students.

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### *Schools*

28. The variations between schools in the teaching of science, (including specialist schools, academies and Community Technology Colleges) are quite substantial and when studying nationwide there are areas with some very good practice juxtaposed locally to areas of poorer practice. A system for networking schools to exchange ideas and resources for best practice would be highly beneficial if it were to be implemented effectively.

29. Analysis by the DfES has demonstrated that students are far more inclined to pursue science at A level if they have taken separate science GCSEs rather than combined science. However, two-thirds of schools do not offer separate science GCSEs. If we are to increase the number of students pursuing A levels, we need to increase the national entitlement to separate science GCSEs, if only for students performing at the higher levels at KS3.

30. Technicians are currently not made aware, or are not involved in, the changes to the Key Stages and there is a risk is that they will be lost from the teaching team rendering practical work more difficult to negotiate.

31. Learned Societies and other organisations produce excellent educational resource materials for use in science teaching in schools. They usually target these towards the National Curriculum because they know that teachers will not use them unless this is the case. However, this fails to exploit the specialist knowledge within Learned Societies, which could be channelled into exciting extension activities if teachers had the flexibility to use them. This stifles innovation and misses an opportunity to enthuse the next generation.

### *Openness*

The Biosciences Federation is pleased for this response to be publicly available and will be shortly placing a version on [www.bsf.ac.uk](http://www.bsf.ac.uk). Should the Committee have any queries regarding this response then they should in the first instance address them to Dr Caroline Wallace, c/o Institute of Biology, 9 Red Lion Court, London EC4A 3EF, email: [c.wallace@iob.org](mailto:c.wallace@iob.org), tel: 020 7936 5970.

## APPENDIX

### Member Societies of the Biosciences Federation

Association for the Study of Animal Behaviour	Genetics Society
Biochemical Society	Heads of University Biological Sciences
Bioscience Network	Heads of University Centres for Biomedical Science
British Andrology Society	Institute of Animal Technology
British Association for Psychopharmacology	Institute of Biology
British Biophysical Society	Institute of Horticulture
British Ecological Society	Institute of Zoology
British Lichen Society	Laboratory Animal Science Association
British Mycological Society	Linnean Society
British Neuroscience Association	Nutrition Society
British Pharmacological Society	Physiological Society
British Psychological Society	Royal Microscopical Society
British Society of Animal Science	Royal Society of Chemistry
British Society for Developmental Biology	Society for Applied Microbiology
British Society for Immunology	Society for Endocrinology
British Society for Medical Mycology	Society for Experimental Biology
British Society for Neuroendocrinology	Society for General Microbiology
British Society for Proteome Research	Society for Reproduction and Fertility
British Toxicological Society	Universities Bioscience Managers Association
Experimental Psychology Society	UK Environmental Mutagen Society

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**Additional Societies represented by the Institute of Biology**

Anatomical Society of Great Britain & Ireland	Galton Institute
Association for Radiation Research	Institute of Trichologists
Association of Applied Biologists	International Association for Plant Tissue Culture & Biotechnology
Association of Clinical Embryologists	International Biodeterioration and Biodegradation Society
Association of Clinical Microbiologists	International Biometric Society
Association of Veterinary Teachers and Research Workers	International Society for Applied Ethology
British Association for Cancer Research	Marine Biological Association of the UK
British Association for Lung Research	Primate Society of Great Britain
British Association for Tissue Banking	PSI—Statisticians in the Pharmaceutical Industry
British Biophysical Society	Royal Entomological Society
British Crop Production Council	Royal Zoological Society of Scotland
British Grassland Society	Scottish Association for Marine Science
British Inflammation Research Association	Society for Anaerobic Microbiology
British Marine Life Study Society	Society for Low Temperature Biology
British Microcirculation Society	Society for the Study of Human Biology
British Society for Ecological Medicine	Society of Academic & Research Surgery
British Society for Parasitology	Society of Cosmetic Scientists
British Society for Plant Pathology	Society of Pharmaceutical Medicine
British Society for Research on Ageing	UK Registry of Canine Behaviourists
British Society of Soil Science	Universities Federation for Animal Welfare
Fisheries Society of the British Isles	
Freshwater Biological Association	

**Additional Societies represented by the Linnean Society**

Botanical Society of the British Isles	Systematics Association
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**Examination of Witnesses**

Witnesses: DR COLIN OSBORNE, Education Manager (Schools and Colleges), Royal Society of Chemistry; MR DANIEL SANDFORD SMITH, Education Manager (Schools and Colleges), Institute of Physics; PROFESSOR MARGARET BROWN, Committee Member, Advisory Committee on Mathematics Education; PROFESSOR MARTIN TAYLOR, Physical Secretary and Vice-President, Royal Society; and DR SUE ASSINDER, Chair of Biosciences Federation Education Committee, examined.

**Q96 Chairman:** Welcome, Professor Taylor, Professor Brown, Dr Osborne, Dr Assinder, and Mr Sandford Smith. Welcome and thank you very much for coming to answer our questions. You have heard how we proceed. I think you were all here during the previous session so would you please introduce yourselves and make an opening statement if you wish. If you do not wish to, then we will go straight into the questions.

*Professor Taylor:* I am Martin Taylor and I am Vice-Chairman and Physical Secretary of the Royal Society. I would like to make an opening statement but I get the idea that I wait until the cycle of introductions are through. It will be brief as well.

**Q97 Chairman:** If it could be brief, as we do like to concentrate on our questions.

*Professor Brown:* I am Margaret Brown, Professor of Mathematics Education at King's College London and I am a member of the Advisory Committee on Mathematics Education.

*Dr Osborne:* I am Colin Osborne, the Education Manager for the Royal Society of Chemistry.

*Dr Assinder:* I am Dr Sue Assinder. I am the Chairman of the Biosciences Federation Education Committee and I am Head of the School of Biological Science at the University of Wales, Bangor.

*Mr Sandford Smith:* I am Daniel Sandford Smith. I am the Education Manager at the Institute of Physics.

**Q98 Chairman:** Thank you. Professor Taylor?

*Professor Taylor:* I just wanted to make the point how very high up the agenda science education is at the Royal Society at the moment. I just wanted to mention very briefly four initiatives which will place some kind of context for the points I want to try and make in the course of our discussions. The first is that today the Royal Society has announced a new Director of Education. It is our first ever Director of Education so that is our commitment as it were, and it is Professor Michael Reiss who is going to be

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Dr Colin Osborne, Mr Daniel Sandford Smith, Professor Margaret Brown,  
Professor Martin Taylor and Dr Sue Assinder

seconded from the Institute of Education. I now hope to bring some blushes to Margaret's face. The Royal Society jointly with the Joint Mathematical Council helped set up ACME, the Advisory Committee on Mathematics Education, and this has helped provide the mathematics community with a single voice to government on maths education issues. We are very impressed with the way that it has gone and we rather think that science education could do with a similar kind of mechanism which the Royal Society, working with other learned societies could try to bring together. You will see in our submission at 3.7 that we have commissioned some work from PricewaterhouseCoopers to try and help bring such a mechanism to bear. The third thing that I wanted to mention briefly, and I have to be a little coy about this because it is with the DfES, is that together with government and in particular the Royal Academy of Engineering, further to Sir Alan Wilson's work on the STEM mapping project, we are trying to work at a grouping that would help bring coherence to the way STEM is delivered. I think the DfES are hoping to make a submission to this Committee and you could explore that with them. I cannot go further, I believe. Then the final thing I just wanted to mention, a thing that has consumed a lot of my time, is that the Royal Society has a very large project indeed at the moment on science education and the economy which you can think of as the supply and demand of scientists. In particular, it is relevant to Next Steps because once you think of trying to produce more scientists, it is not just in terms of more A levels but where they are coming from at primary level right the way through to where they are going in higher education, so that would be the relevance of that. Thank you, my Lord Chairman.

**Q99 Chairman:** Thank you for that. Let me ask the first question which is, how realistic are the Government's targets in Next Steps to increase the number of pupils taking A levels in physics, chemistry and mathematics? How could these targets be achieved and what would be the implications in terms of teacher numbers and class sizes? I leave it up to you who jumps in first on this one. Who would like to start?

*Mr Sandford Smith:* I will try and start with that one. They are extremely ambitious targets because, as has been indicated, we are about to see a decline in the number of students taking A level sciences, so to reverse the decline, particularly in physics, which has been in decline for a long time, is very ambitious. We are very happy to see it recognised as a serious issue for the country that the decline is a problem, and to see a recognised ambition. We would like to see more about how that ambition is going to be realised. The second part of your question, about what that might

do in terms of class sizes and whether that increase in numbers can be supported, is really an issue about where the numbers come from. There are some very successful schools which produce large numbers of students. If those students come from those schools they will not be able to support the kinds of increases that generate those numbers but if we can get to the less successful schools, we believe there is probably some capacity in those schools to increase their A level numbers. So, for example, in A level classes you may find a number of classes where there are less than 10 students so you could increase the numbers in there without serious problems, but if you are talking about a school where their class size is 20, you would need to start adding extra classes.

**Q100 Chairman:** Would one of the others of you like to chip in here? Professor Brown?

*Professor Brown:* If I could come in about mathematics. I think they are, as has been said, ambitious targets but there are a few ways in which we could try and meet them. One is that as a nation we are not really as aware of the importance of mathematics as we might be. It is the first chapter of Adrian Smith's excellent report which points this out. In almost every other country in Europe, and indeed in South Africa where I was this weekend, every child has to study mathematics until they leave school. England and the UK in general is one of the few countries that does not think mathematics is important enough to organise that. So a realisation that it is important not just for supporting science but for supporting many other subjects in higher education, as well as in its own right. Some universities find that 70 per cent of their students end up doing a subsidiary subject in mathematics and yet when they select their A-levels they are not aware of the fact that they will have to do mathematics in higher education. So there is a need to make students aware. In particular, there are students who carry on with physics and biology and chemistry at A-level and there are a lot who do not seem to be aware of the fact that universities would hope that they would have an A-level in mathematics to support the sciences. So I think we need a greater awareness of the role of maths in these subjects, particularly in higher education but also in graduate employment. We know why students do not carry on into A-level with mathematics and it is largely because it is said to be hard and boring. I think we can do something about both of those two factors. We can make it less hard and we can make it less boring if we try very hard.

**Q101 Lord Howie of Troon:** You both described the targets as "ambitious" but you were actually asked whether they were realistic.

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*Professor Brown:* Right, yes. I find it very difficult. I have very little evidence to know whether we can achieve them and whether they are realistic. I find it difficult. It is worth aiming to achieve them. I have no problem with aiming to achieve them, but I do not feel I can actually say whether we would achieve them with any great certainty.

**Q102 Lord Howie of Troon:** You would be delighted but perhaps surprised if they are reached?

*Professor Brown:* I would indeed, yes.

**Q103 Lord Paul:** Just a very short question, Professor Brown. How will you make the subjects less hard? How can you make the subjects less hard, by reducing the A-level?

*Professor Brown:* I think there is a temptation to say that we dumb the subjects down and that is clearly what we must not do. One of the problems that students have is that they feel that they are not very good at maths. This is not just students who have a B at GCSE or even an A at GCSE. We have quite a significant number with an A\* at GCSE who do not believe they are very good at maths. This is largely because of the way the subject can be taught and in particular in Key Stage 4 where people are practising very hard for examinations, we have a recent Ofsted report which shows that the quality of teaching in Key Stage 4 has dipped because of rehearsal and coaching for examinations. When students are taught routines for doing things that they feel they do not understand, they feel that it is hard. Actually if we aimed at giving them a better understanding, not necessarily making it easier in the sense of dumbing down what is required, they would feel more capable at what they know.

*Dr Osborne:* I wanted to make a point as to whether the targets are indeed the right ones because our evidence looking at the statistics of people doing A level chemistry is that very few of them, less than 10 per cent, transfer on to higher education. It seems a simple thing to do would be to try and encourage better transfer rates to higher education in the science subjects rather than these students going on to law, accountancy and all these kinds of things. One of the things there I think is certainly much better careers advice in schools and colleges.

*Dr Assinder:* My Lord Chairman, just to make a general comment about getting more pupils to take A levels across all the sciences, I think the targets, however realistic they may be, are only going to be achieved by enhancing the learning experience of pupils up to 16. It is no good concentrating on improving achievement; you have got to improve engagement with the subject, and that comes down to how it is taught as well as what is taught. I would make a comment from the perspective of the

biosciences because it would be easy for us to be complacent at this point. I can assure you that bioscientists are not complacent, because clearly the requirement for bioscientists to be literate in maths, chemistry and physics is the only way forward in terms of making use of the inter-disciplinarity of the sciences these days, so we are as concerned as the other societies to improve uptake of all science A levels.

**Q104 Lord Mitchell:** When we were talking about making the subjects less hard, and I understand we do not want to dumb them down but make them more interesting, it seems to me that an awful lot of high-paid jobs today, you could look at something like mathematics as a subject, and there are a lot of jobs today in the City of London, for example, paying phenomenal amounts of money to people who are good at maths, but I would bet that most kids going through have not a clue about this. They just see maths as a rather dull subject that you have to get in order to perhaps get into university, or wherever you are going, to be abandoned at the first possibly opportunity. I think that may be true of some of the other science subjects as well. It seems to me that there is a real case for being able to explain to children that this is a way you could get into something that could be really interesting, pay you an awful lot of money, and you would be very successful at it.

*Professor Taylor:* I wanted to respond to Lord Mitchell and then make another point, if that is okay. First of all, the Government produced a report a little time ago and they highlighted that it was not primarily mathematicians in the City of London that were desirable; it was people who could model situations who were the prime targets, and these were the physicists and engineers. So your argument pertains over a lot of the physical sciences, yes. On the question of the realism of the Next Steps ambitions, one has to think about the pool of people who are going to become this increased number of A level students. The first observation I would make is that, in fact, due to the decline in birth rates such an increase is even more challenging than one might first have thought. I would also very much agree with Dr Osborne that progression is the way to look at things. We note in particular that a lot of people do not progress to A level from AS level. I think that would be a good target to try and aim at. I note also that there is very little said about further education in a lot of the documents that we have received from the DfES. 25 per cent of A levels come from people going through further education and I think that is something that needs to be looked at. I agree with the point about careers. I should stop there.



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**Q105 Chairman:** We have seen some fairly convincing evidence that GCSE and A levels in science subjects are more difficult than in other subjects. What do you view as the impact of this situation and what can be done to remedy it?

*Dr Osborne:* I think students these days are very sensible and they know this. They realise they have to get a certain number of points to go to university, so often they choose to take subjects that are perceived to be (and indeed may be) easier by up to a grade or a grade and a half. I am not suggesting either that we should be dumbing down the sciences or mathematics. What I am suggesting is that perhaps some of these other subjects should be made harder, which would not be a difficult task but would be remarkably unpopular with many of the other subjects.

**Q106 Chairman:** Some of these subjects might be broadened beneficially by adding some maths and science to them?

*Dr Osborne:* Indeed.

**Q107 Chairman:** Mr Sandford Smith, perhaps I could ask you what you are doing to address the serious gender imbalance amongst pupils opting to take physics A level?

*Mr Sandford Smith:* We commissioned some research to look into the issue. There have been a lot of initiatives to try and attract more girls to study physics post-16, so we commissioned a review of all the research that has been done in this area. It has to be said there is not a simple answer. Most teachers would like a very simple solution to attract more girls into physics, but the key issue from research is that it is the quality of teaching that matters and if you do not improve the quality of physics teachers in schools, you will not be able to address the problem of the number of girls going on to study physics. In a sense, from the Institute's point of view what we will be doing is pushing the Government to increase the number of physics teachers in schools.

**Q108 Earl of Selborne:** I would like to ask our panel whether they are concerned that school pupils are required to narrow their options too early? They do not realise some of the options that might be available to them if they continue with a wider curriculum. It seems to be one of the problems of the way we structure our curriculum, following Lord Mitchell's point about advice to pupils about the options which may arise in their career. What more could be done to advise pupils before they get to a critical cut-off point about the career opportunities that might be opening up for them with either science or mathematics?

*Mr Sandford Smith:* If I could do the careers part, we do see careers as a serious issue and there are limited things as an organisation we believe we can do with the help of government. However, there is a more fundamental issue about careers advice in schools and the impact that it is having. First of all, on this comment about the difficulty of subjects, we hear horror stories of careers advisers advising students not to do the sciences because they are more difficult. One of the solutions we see is to try and pool all of our resources to provide information for students and for teachers and for careers advisers about the options in science. Under the auspices of the Science Council we are working together to try and produce a website that would contain the information that promotes those careers, but the Science Council does not have sufficient funding to produce that kind of website. The Government has indicated a willingness to work with the Science Council but as yet there is no funding forthcoming.

*Professor Taylor:* I would just like to start by agreeing with some of the points that I think were behind Lord Selborne's question. I think our current A level system, when it asks people to choose three A levels, is implicitly asking them to choose away from an awful lot of other things. I note that the Tomlinson Report had started to look for some flexibility there, maybe a diploma system, maybe something like a baccalaureate system, something that was wider and left children up to the age of 18 not having rejected so many things. I think that would be quite welcome. Part of this—a point that Margaret Brown has already made rather well—is that mathematics is providing something of a bottleneck. It is maybe looking at her observation from the other way round. For the physical sciences, to go on and do higher education, nearly everyone has to do mathematics so the number you are ever going to get into the physical sciences is pretty much predicated on what has happened in the maths A level system. That is one source of the worry. I would also worry a little bit about the options that are offered to 14-year-olds. I think it is quite a complex world of options that are being offered to them with three separate sciences or two sciences and 21st century science and applied science. I know that even some of the science teachers feel a little bit bemused by all the different options that are around. A further point on careers. Careers is one way to enthuse young people. Another way that has not been explored yet, which we found very helpful for enthusing young people, is to get scientists into schools and scientists to work with young people. One of the greatest things about education is when you can inspire young people, and that has worked very well. The Royal Society Partnership Scheme has got in touch with 40,000 students over the last five years, something like that. I think this

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success should be built on more nationally. The Royal Society can only do things well at a small level. It is a great idea but it needs building on.

*Dr Assinder:* If I could just follow that up, my Lord Chairman. I very much endorse what has been said about getting scientists into schools, with one caveat. Coming from a higher education background, scientists doing work in schools is at best unrewarded and at worst actively discouraged at a time when the funding of universities is very much focused on research activity. So those sorts of activities are not well supported. I am a recipient of a Royal Society Partnership grant and it is an excellent thing to get into schools, but I am a head of department so I have allowed myself to do it but not all heads of departments do.

**Q109 Earl of Selborne:** Do you allow your colleagues to do it?

*Dr Assinder:* I do allow my colleagues to do it as well, yes.

*Professor Brown:* Could I just add one or two things about careers. There is a new Higher Education Funding Council grant for mathematics to attract more students into mathematical sciences and that has quite a big push on careers. I hope that will bring up some of the points that were raised by Lord Mitchell. One or two other points. One is that I think on choice of subjects there is an excellent report by the QCA about the selection of mathematics for A and AS level. It points out that the numbers of students who carry on doing mathematics, physics and chemistry as part of their offering has dropped by 50 per cent between 2001 and 2003. It is assumed that it must be due to the Curriculum 2000 which encourages students to take a wide choice of subjects that schools now offer which were not maybe hitherto on the curriculum, like psychology or photography or other things. It does seem to have had a quite drastic effect in reducing the number of students doing the normal offering of mathematics/physics/chemistry or mathematics/chemistry/biology which is down to 60 per cent of what it was in 2001. There is a concern, I think, that whereas we cannot go back on the Choice agenda it is actually having some frustrations from the science point of view. I would just say that one of the problems in students selecting A levels is that in mathematics some teachers actively discourage students from taking up mathematics A level if they are not in the top set. There is a kind of feeling we only want students to do this subject if they are going to do extremely well at it, and we are not encouraging students who might get a reasonable A level and then use it to support their other subjects later.

**Q110 Earl of Selborne:** I want to follow up Mr Sandford Smith's point about the Careers from Science website: it does sound as if the money is not going to be available. Should we as a select committee do something to help get this funded? It does seem to be an obvious opportunity. People refer to websites for all sorts of matters, not least I would hope for advice on careers and science.

*Mr Sandford Smith:* I believe discussions are on-going so positive feedback from your Lordships will be very welcome in terms of stimulating that discussion. The professional institutes have put a certain amount of money into this website and there is a project officer appointed to try and keep it going. The problem is that when young people are used to web technology, we have to provide a very high-quality resource and that is not cheap to do.

**Q111 Earl of Selborne:** So it is happening?

*Mr Sandford Smith:* Yes.

**Q112 Earl of Selborne:** But it has not yet got to where you want it to be?

*Mr Sandford Smith:* Yes.

**Q113 Lord Howie of Troon:** A very brief point. Professor Brown said you could not go back on choice. Why not?

*Professor Brown:* Well, it is not easy. Once you have let the genie out of the bottle, I think it is quite hard to say to students that last year's students were allowed a free range of choice and you are not. Probably what we have to do is to work on the other side which might be to persuade our universities—and I speak as one of the members of them—to encourage students to take up the subjects that would be useful at university level. I think too many universities are happy to accept people when they do not have the qualifications they really want. I have been talking to users of mathematics this week in a number of user subjects and business and management are desperate because students do not come in with more than a GCSE grade C and they have to teach them the process of management. Students enter some of the science subjects, things like pharmacy, with no mathematics since GCSE. All these universities are desperate for more mathematics and yet nobody will stand up and say so. If they would only say, "You can only get into Oxford to do a PPE in economics if you have got a maths A level", or "We will only let you in to Cambridge to do physics if you have a maths A level". I believe that is the case but nobody actually says so, so you get students thinking they are going to get into Cambridge to do physics when they do not have maths. So I do think the universities might give more

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of a lead in advising students what sort of subjects are required, but I think reversing choice is difficult.

**Q114 Lord Howie of Troon:** You clearly do not think that letting the genie out of the bottle was a very good idea. Could you not encourage them to put it back in?  
*Professor Brown:* I think that is for you to suggest. I think we would find it quite difficult to persuade politicians to do that.

**Q115 Chairman:** I would observe that there is a downside to that because what I worried about a great deal in Cambridge was the fact that most of the engineers were encouraged to do nothing but maths and physics from the age of 14. I think it would have been hugely beneficial if they had carried English through. Every other country requires that except for this country so we produce these overly narrow students. I am afraid it is my observation that it is the universities that are very much to blame for this because they say endlessly, "All we want is two maths and physics," and I think that is far too narrow a curriculum for students from the age of 14.

*Professor Brown:* I think that may be true for engineering. I think it is less true for other subjects maybe.

**Chairman:** I am not sure. Lord Mitchell?

**Q116 Lord Mitchell:** I would like to go back to the careers side, if I could. Two personal comments: first of all, I am Chairman of a company that is in IT services and I can say as an employer that finding young people to come and work for you is really difficult. They are not bashing down the door. It is tough to find them. On an even more personal basis I have a son who is just doing A levels and he took AS levels in science, and one of the things he wanted to do to make sure that his university application form was good was to do some work experience. So I contacted a small biosciences company and when I contacted them they said that nobody had ever approached them before to do something like that. They were thrilled to do it and they would like to do it for more people. I just wonder if there is a case for the American internship system that they have where young people do spend time in companies and in all sorts of places just to get a feel for what life is like. Maybe that is something we could encourage.

*Dr Assinder:* One of the things that the Biosciences Federation is doing is looking at employability. We had a colloquium last year at which we tried to bring together school teachers, higher education representatives and representatives from industry to try and have all the people packed in the same room. Unfortunately, we could not get many people from industry but those that were there were very supportive of the sorts of initiatives that we were

proposing, and it was exactly the sorts of things that you are saying, that we should be getting students out into the workplace as part of their school curriculum, but it is not easy to do that. The other option is to try and get them, for example, into university laboratories, which we do in my department but again you come up against these issues of whether that is a good use of an academic's time to be looking after an A level student in their laboratory?

*Professor Taylor:* I want to endorse Lord Mitchell's question/comment but from another way on. As I said earlier, we have got a supply and demand project going on at the Royal Society still to some extent in hand and the key thing that came up quite early was asking employers what it was they really wanted of graduates. The first thing that came up was, "We love students that have had work experience." Sometimes it is quite hard to get them to articulate exactly what it is they like about such students. It may be that they observe greater commitment in such students or it may be the intrinsic experience itself, we are not sure, but it is certainly very high in what employers are after. I am sure that as our project develops we shall try and explore what can be done in that regard.

*Mr Sandford Smith:* We get a number of students asking us to help arrange work placements. We find it very difficult to satisfy that demand. We produce a booklet listing the companies that have offered work placements but it almost shrinks year on year. I think if we could as a community do it, it would be wonderful but it needs commitment from industry to do it, particularly perhaps in physics. We are quite SME-based so it is very hard for them to find the personnel to actually manage work experience, I think.

**Chairman:** Let us move on. Lord Paul?

**Q117 Lord Paul:** Before I get to my science question I have a question for Professor Taylor. Can you tell me what Physical Secretary means?

*Professor Taylor:* It does not mean that I am strong and muscled or anything. It means that I am in charge of the physical sciences. We have a Biological Sciences Secretary and a Physical Secretary, so I am in charge of mathematics, physics, chemistry, engineering, geology and astronomy.

**Q118 Lord Paul:** Why is there a shortage of specialist physics and chemistry teachers, but less of a problem with biology and mathematics? Are the Government's targets on specialist teachers in Next Steps appropriate and what are the prospects of these targets being met?

*Dr Osborne:* The first part of the question I think is easy in that the recruitment to teacher training for many years has been supply-led not demand-led. Many more biology graduates come out of university

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so the Teacher Training Agency, as it was then, set targets for training providers where it reflected really the numbers graduating rather than the requirement within the system for more chemists and more physicists. I think the targets on specialist teachers are certainly appropriate. Whether they would be met or not depends on what we can do to actually use novel routes to get more people into physics and chemistry as teachers. For instance, there are chemistry and physics enhancement courses where people who do not have a sufficient background do ITT training. There may be a case for taking many biology graduates and trying to persuade them to become physics teachers or chemistry teachers, but I suspect they will need an inducement to do so.

**Q119 Lord Paul:** How successful has the Student Associates Scheme been at bringing science and mathematics graduates into teaching? What are the Institute of Physics and the Royal Society of Chemistry doing to ensure that an appropriately large proportion of students on the scheme are physicists and chemists?

*Mr Sandford Smith:* I do not think I can really give you any evidence on that, I am afraid. We have worked with the Student Ambassadors Scheme and we believe that it can be quite successful in persuading physicists that teaching is a career that they should consider at the end of completing their degree, but I am afraid I do not have any actual evidence of how many of those people do then go into teaching.

**Q120 Lord Paul:** Do you find excitement amongst students to be teachers when you give them that opportunity? When I was a student I was given that assignment and I was over the moon at the opportunity. Do you find that?

*Mr Sandford Smith:* My understanding is that in the universities who operate that kind of scheme it is voluntary so the ones who are doing it will be positive about it and do have a positive experience. I am sure that is right. In a sense, it would not be sensible, for the schools or the students, to make that mandatory.

**Q121 Lord Paul:** What are you doing to encourage qualified scientists and mathematicians to move mid-career into school teaching?

*Dr Osborne:* One of the things we have done is a joint report with the Institute of Physics which we commissioned from PricewaterhouseCoopers where we looked at the rewards of various careers. It compared whether you did A levels or not and whether you did university degrees or not. Within that as an organisation we produce annually a remuneration survey for our members so it is fairly clear where the salaries of school teachers lie on that.

Certainly to start with school teachers appear to be much better paid than university academics and the equivalent of industry but as time goes on there appears to be an upturn in the graph of people, particularly in management in industry. So the evidence is there for people to make their own decisions.

**Q122 Chairman:** Did this report address the issue that we have discussed on some of our visits to schools that people in mid-career find it difficult socially to go back or to enter schools for the first time and cope with a classroom of young people? Is that not a key issue to consider?

*Professor Brown:* I can only answer from some experience anecdotally from one institution and that is sometimes the case, that people find it very difficult to be a junior member of staff. I can say a little bit about the question you asked our predecessors about why people leave teaching. Conditions of service is one of the reasons and the fact that there has been (until recently anyway) insufficient support. People do not have nice offices, they do not have their own computers necessarily, they do not have clerical support. Schools are moving in this direction and the situation is very much better than it was some while ago but the conditions of work are certainly worse for most people who switch into teaching. As you say, being a junior member and finding, particularly, that the students challenge you, which your employees presumably did not to the same extent before, these are some of the problems people experience, but I am not aware of any kind of firm evidence on this.

**Chairman:** Baroness Platt wanted to make a point and then I will come to Professor Taylor.

**Q123 Baroness Platt of Writtle:** Just taking up what you said, keeping discipline is a very important thing and one that somebody who is a returner will find more difficult. One has read quite a lot recently in the paper of people who have had very demanding, highly-paid jobs in the City and are suddenly saying, "I think I would like to stop this now and put something back into society". They might be the people you could attract. I would also suggest as patron of the WISE Campaign that there will be married women returners who might have been engineers, who might have been in the City, who might have been doing all sorts of other things who when their families come would find it more convenient to teach, as long as they can get home for tea or have proper school holidays and so on. All these things need to be thought out in some detail if you are going to attract them because it has got to be made attractive, has it not?

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*Professor Brown:* I think that is right. I think we need to do more. The arrangements for training in school (GTP schemes) do make it slightly more attractive because they pay slightly higher salaries, but I do not think we have really thought about what the costs are for somebody changing over. I think we could be more generous in what we provide.

*Professor Taylor:* This discussion reminds me very much of a related and neighbouring one, the topic of retention rates amongst teachers. The statistics I have seen are in the order of 50 per cent of teachers coming into the profession are lost within the first five years. We have a project on-going at the moment with Sheffield Hallam University and we have asked them *inter alia* to look at what is positive and what retains teachers. What do they like? It is very similar to the things I have just been hearing: a disciplined environment; distributed leadership where everyone is involved in decision-making; a good buddying or mentoring system; a no-blame culture; and a well-planned induction system for the new staff.

**Q124 Baroness Platt of Writtle:** Of course.

*Professor Taylor:* I would also add this reminds me of a further thing, we had a seminar at the Royal Society recently to go through very carefully four excellent and very different schools who were doing well at A-level science and you would have found bullet points just like those. Those were the things that made them successful.

**Baroness Platt of Writtle:** I think they are very interesting. We shall need to copy those down.

**Q125 Chairman:** I am sure we have them recorded.

*Professor Taylor:* There is a longer list if you would require it, Lady Platt!

**Q126 Lord Mitchell:** Just a final point on this, I must say I am aware because of my twin sons, who were at Westminster School just over there, they had a fantastic headmaster who retired at 58 who was a brilliant maths teacher. He then wanted to go into the state system to teach maths and he could not get in. I just cannot understand it. It was impossible for him to get into the state system. It seems to me there must be huge numbers of qualified people in their 50s who are not really interested in the money at all, they just want to put something back and do something that is enjoyable, and there must be huge blocks that prevent them from doing it and huge opportunities for us as a society to bring these people back to make some contribution. Now I shall ask my question. How effective are the various enhancement courses in improving teaching standards amongst new teachers? What could the Government do to encourage greater take-up of such courses?

*Professor Taylor:* That might be me. The RSC and IoP are supremely well-placed to answer.

*Mr Sandford Smith:* I am assuming by enhancement courses you mean the recently developed enhancement courses which are run by the TDA. They are pre-PGCE courses to take someone without the relevant degree in chemistry or maths, put them through some subject knowledge for six months before they then start on a PGCE. We have had the first cohort going through schools this year so it is really too early to be clear about what the long-term implications would be for the graduates of the scheme who would make good teachers. One of the issues initially was recruitment onto the pilot and a number of people who were recruited were never going to be teachers, it would not matter what subject they were teaching in. We believe it can be done. There are issues about how it is funded, so for someone who starts they are funded for the enhancement course but then have the summer break where they are not funded and they are not entitled to any loans system or anything like that, so there are things that could be done to make it more attractive in terms of the financing. There is also a lot of work to be done in terms of the publicity for some of these sorts of courses. One of the problems we have is that science and maths are particular issues in terms of recruiting teachers, but we tend to see generic recruitment rather than trying to work out where the potential teachers are and where you would target them. I think there is more work that could be done in targeting people properly.

*Dr Osborne:* If I could just add to that, chemistry is slightly behind physics in that we have just completed a pilot but the problem is that the TDA are wanting to have a national roll-out and they are having great difficulty in finding higher education institutions who wish to participate. I think there should be a greater inducement for the higher education institutions to run these kinds of courses.

**Q127 Earl of Selborne:** We have been told that the emphasis on testing in schools and the “bunching” of government initiatives are hindering teachers from doing their job properly. So what alternatives to the current testing system would you propose?

*Professor Taylor:* I would start with a couple of observations. To my mind, testing is there for at least two reasons. One, it is there as a quality control given that the government puts a lot of money into education and they want to see what value is coming back and how we look on the international scene compared to others. That is all quite good and reasonable. Then there is also testing as a diagnostic to help the child as well, some kind of formative assessment. As regards the qualitative control, I have some quite strong words. I think a lot of the formal

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tests are no longer quite fit for purpose. I would much rather, I think, see some kind of sampling technique. If the government wants to know how well we are doing, we do not have to be testing the whole nation at all these different stages, it would seem to me. As regards what I would call the formative assessment, perhaps the more exciting—and if you can get the other bit to retreat maybe you can do more with the formative assessment—then there are some quite innovative methods around, and Margaret knows much more about this than I do so I am just trying to set the way for her, I think. There is e-assessment and my understanding is that students quite enjoy e-assessment. There are student portfolios and presentations. Once you have got the heat off things you can enjoy your assessment and use it to help the child and you are no longer teaching to test, which is one of the constant things we hear at the Royal Society that is ruining education at the moment.

**Q128 Chairman:** Professor Brown?

*Professor Brown:* To take that up, the distortion of the curriculum and the effect of negative attitudes to maths and science because of the current examinations (particularly the GCSEs) are probably the most important factors that are working in education at secondary level. If we could change one thing it would be the nature of those GCSE examinations, certainly in mathematics and probably in science as well. They are very technique and knowledge-based and they do not give sufficient value to initiative and to investigation. We have, of course, had coursework but coursework, although well intended (and in its early years it seemed to work relatively well) has become much more of a routine and plagiarised activity. I think we really have to grasp this nettle and do something about it. The other point of course is the pressure on teachers with league tables. So it is not just the nature of the examinations; it is the fact that teachers are under greater pressure to get students through, particularly in science and maths, and perhaps even more so in maths because the five GCSEs have to include maths and English from now on. A great deal of their effort therefore has to go into dragging children who would get Ds into Cs. The priorities at Key Stage 4 have to be a narrow band of children which are not necessarily the ones we might think are the most important at that stage, although all children obviously have rights to be important. Even if, for example, we used a points score, it would give equal value to all children so there would be equal incentive for all children to progress rather than just those they had to get over the C/D boundary. The whole business of the nature of the examinations is linked with the pressure of the league tables and it is rather difficult, again, to see how we can escape that. We need broader assessment styles

and we also need more teacher assessment, but there is a problem with that which is that it increases workload. So it is very difficult to see how to move at the moment into more teacher assessment without attending to the workload. When we did have in the past more teacher assessment, and I was associated with a graded assessment movement which gave GCSE grades for both mathematics and science on 100 per cent teacher assessment, that was not only valued by teachers and students but it seemed to give a lot more professional development to teachers because they had to work out how to assess and how to set up the assessments for their students. So I think it has a payoff not just in student attitudes but in teacher professionalism and teacher attitudes as well. It is clear that there is a workload issue and I think it is difficult to see how to move directly to that without considering the workload aspect of it. Just to answer the second point about government initiatives—and many of these are also involved with the assessment scene—there is no doubt that teachers are complaining and one of the reasons for people leaving teaching is the fact that they are having to cope with one initiative after another. It also means not only are they forever looking at new syllabuses for different examinations, it is either a change at A level or a change at GCSE, and there have been changes I think every year in the last eight years or something like that, it is a frightening statistic; it also means that those who produce resources like textbooks and materials on websites and so on have to keep revising these, and the quality of them, frankly, is going down. This links again back into the examinations. The examination boards tend to have a monopoly of the textbooks and they can be extremely boring and very exam-related textbooks and they just get rewritten every time we change, without improving the quality. In fact, in many ways the quality goes down every time they are rewritten. A lot of things come together in the examination system and it seems to me very important to try and break our way out of this some way or another.

**Q129 Earl of Selborne:** I think I heard Professor Brown start by saying that we needed to be more imaginative in the content of GCSEs and then go on to say “but do not change them any more” or that we have too many changes. Perhaps I misheard. This raises the point if there are these new science GCSE courses being rolled out under Nuffield which in fact, from what we have heard, sound as if they do indeed capture the imagination of GCSE pupils perhaps in the way that previous courses did not, but if they are being rolled out and there have only just been pilot schemes, they clearly need time to bed down and the teachers need time and they need the resources. Are they getting them? Are we in danger of rushing

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another course out without suitable preparation and suitable courses?

*Mr Sandford Smith:* This might be not entirely an answer but the evidence would suggest if we are to have new A levels in 2008, after two years of teaching the GCSE and new Key Stage 3 curriculum in the same year. Science teachers will need to get the GCSEs right in two years, in a sense that means they are not going to have a chance to revisit what they have done and find more creative ways of teaching the second or third time round. So I think it is being rushed through and it will be ineffectively rushed through.

**Q130 Lord Howie of Troon:** I am wondering where these initiatives and distortions originate, and I know it is the government but the government could not have thought it up by themselves. They must have got the idea from somewhere and where is that somewhere? Is it educational theorists or what?

*Dr Osborne:* I have to say for the new science GCSE the science education community must blame itself because they considered that what we previously had was stultifying and rather boring so decided to do something about it, and also to make sure that the science that was being taught was not just science for those who were going to continue with science and become future scientists but also be a background for those who were going to finish their science at the age of 16 but would need to know about science as citizens. So from that point of view that is where that one came from. To reflect a bit more on this business, there is much new science in the new GCSEs and many of the people teaching it will not have studied that science themselves and because they do not have an entitlement to CPD, they are not getting the background in that material in order to put it across in an exciting and engaging way to their students.

**Q131 Lord Howie of Troon:** I know what you mean. I abandoned structural engineering design when it went metric!

*Professor Brown:* Could I just come back to the point that I think was made by Lord Selborne as well. I think we do need change and the change is produced, as often as not, by the community, I agree. One of the problems however is that we get these gradual changes and quite often the changes are to correct what last time we did not quite get right. So I think what we would be in favour of is a major change every 10 years and everything else was saved up for that, but at the time of that major change there were many more years of preparation, both professional development for teachers and production of resources and that we had trialled these changes more, because certainly the Curriculum 2000 maths got it really badly wrong and the numbers doing

maths dropped by a greater percentage than those for any other subject. It was simply because these things were not trialled, they were not properly consulted upon, and there was not sufficient time given over to it. I do remember at the time the Royal Society said the curriculum was too hard and if the Royal Society says the curriculum is too hard, it is too hard. Everyone could see when the change was about to be implemented that it was wrong but because these things are done too fast we end up on this rollercoaster all the time of correcting things, and this should not need to happen.

**Q132 Chairman:** Professor Taylor?

*Professor Taylor:* I did not really have anything special to add, to be honest, my Lord Chairman. I have a little note written down that I had already thought of the question that Lord Selborne put to us. There was always going to be a tension between not wanting to change the system too much and the need for reform, and the point I had written down is it is vital that first of all it be thought through terribly carefully and there not be too much at a time. I am not necessarily, I have to say, in favour of Margaret's complete change every 10 years, I am more of a smooth change man, but I am sure you can form your own view on these things.

**Q133 Chairman:** We have only spoken to a few people about this and we have been to two schools; in both of those schools overall there was great enthusiasm for a lot of what was in the new science curriculum. Would you agree with that or do you think it is dumbing down? There is terrific emphasis on the students being able to relate to the syllabus and certainly the teachers we spoke to were enthusiastic. Are you all enthusiastic?

*Professor Taylor:* I am enthusiastic. If I can just add parenthetically, I think it is particularly helpful for young women who want to get into the sciences. We find that women love to see science that applies in their life in some way. We were asked a little earlier how we might help in gender improvement and I think that would be one helpful way.

*Dr Assinder:* I am very enthusiastic personally and I cannot wait (if it works) for those students to get to higher education so I can teach them because I am hoping that they will have a much better focus than the ones I teach currently. This makes it very important that we get the A level right because those students will be going on to the revised A level.

**Q134 Earl of Selborne:** That is going to change as well.



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*Dr Assinder:* That is right.

**Q135 Baroness Platt of Writtle:** Most witnesses appear to agree that teachers should have an entitlement—and I think you have mentioned that—to a certain amount of continuing professional development. How important is it for science teachers to update their science knowledge through CPD and should it be mandatory for them to undergo a certain amount of CPD each year?

*Dr Assinder:* If I could answer. How important? Very. Should it be mandatory? I think yes. The issue I have is giving them time to do it. I think that is where the problem comes.

**Q136 Baroness Platt of Writtle:** They need cover, I suppose.

*Dr Assinder:* Absolutely. I have run in-service training myself because I have produced schools resources and I have had the same teachers come more than once to the course I have delivered. At first, I was concerned that was because I had not delivered it very well the first time, but they assured me that was not the case. That was the only day they could get out that year and that was the course that was on. There are real issues of releasing teachers to actually take the opportunities.

*Dr Osborne:* I would add a caution about it being mandatory. I would say there should be an entitlement that they can take up. Mandatory smacks of coercion and that is where the present system of having five inset days a year used within schools, that is one of the reasons why that has failed.

*Professor Taylor:* That was the point I was going to make, my Lord Chairman.

*Professor Brown:* We now have the definition of the different stages in teaching careers and those refer to CPD, so rather than say it is mandatory you would say in order to get to the next step in your career then you would require it. That is exactly how it is phrased and that is a more positive way of looking at it.

**Q137 Baroness Platt of Writtle:** How confident are you that teachers will continue to attend courses at science learning centres once the existing bursaries are phased out? Can schools afford to pay such fees without financial assistance from the government or elsewhere?

*Dr Osborne:* That is not really a question for us. That is a question for the science learning centres, but there is no doubt that if courses are of good quality schools find the money to take people to them. We certainly find with our courses that providing they are the right sort we do not have a shortage of applicants.

**Q138 Baroness Platt of Writtle:** Then this is a mathematics one. Why is the National Centre for Excellence in the Teaching of Mathematics a virtual centre, unlike the science learning centres? Is there a danger that this will convince head teachers that their mathematics teachers do not need to go on external CPD courses?

*Professor Brown:* I think it probably does reflect a certain amount of learning because obviously the national centre was only opened a week or so ago. It may be the problem of actually getting people physically into centres that has made people think harder about the virtual centre. The aim of the national centre is to have most of the professional development through teachers in their own school or with local schools, which has the advantage, of course, of costing very little, but I think there is the fear—and it was an ACME paper that was behind the founding of the national centre—that the time will not be found for teachers to interact with their fellow teachers in their own and local schools, and we are also concerned that this does not necessarily bring in an element of expertise, which I think somebody referred to earlier. There is a danger that schools that find it difficult to recruit excellent teachers may have no external influence. I think visiting schools that are known to be good is obviously useful and also subject knowledge input through going to external courses at universities and other centres. We do know that teachers who stay in the profession do value the opportunity to go outside school as well as working with their fellows inside it.

**Q139 Lord Howie of Troon:** Apart from funding labs, what can be done to improve the practical work in schools, especially when you realise that teachers often worry about health and safety issues, often mistakenly? How can that be tackled?

*Dr Osborne:* As this is probably more a chemistry problem than perhaps biology and physics, I ought to answer this one. Three of the things have been mentioned already. The first is people teaching outside their subject area where they are not confident in what they are doing. Certainly they may be scared about doing some chemistry experiments. You have the pressure of people doing lots of coursework in a formulaic way and you have got lots of people teaching to the test at virtually every stage throughout their career. There is also the fact that because we live in a blame culture people are very worried about health and safety issues and they become ill-informed because there is, if you like, a perception that you cannot do things and chinese whispers take place so that people think certain experiments are banned. At the Royal Society of Chemistry we decided this was so serious that we decided to commission a survey where we produced

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a report called *Surely that is Banned?* where we sent out to schools a questionnaire where there were 40 experiments which could possibly be banned. Only two actually were and we found it was very reassuring that 90 per cent of schools did know about the two that were banned, which was very good, but many people thought many of the others were banned, and indeed they were not. There seems to be a need for some sort of system where teachers can be told what they can do. Local education authorities are often the employer and they have the right to say what can and cannot be taught within schools. There appears not to be a requirement for there not only to be a list of national things that are banned but also a list of very common experiments that everybody can look at and say yes, you can do it. So I think it is more publicity for teachers to tell them where to find information.

**Q140 Lord Howie of Troon:** You could have boxes you could tick?

*Dr Osborne:* That is right.

**Q141 Lord Howie of Troon:** That would be very good. That brings me to technicians in this respect. There is a certain amount of concern—and we have spoken to some technicians—about their working conditions which are perhaps not terrible satisfactory. Can anything be done about that? Do you think they should play a greater role with pupils in the classroom?

*Professor Taylor:* I could suggest a strategy for getting an answer to that. The Royal Society did some work with the Association for Science Education. It is the ASE that has taken this forward. I think you are going to be talking to them next week, is that correct, my Lord Chairman, so I would suggest from my point of view you take that up with them then. They know quite a lot about that. I wanted to come to the first part of your question and just address what I consider to be the importance of practical work and field work. As I tried to say earlier in some of my answers, I think the educational experience should offer people some opportunities to really be inspired

and fired up by science. Practical work and field work have a real key role in this. The thing is it is very resource expensive. As we were just saying, you need good technicians; you need modern facilities, which might be quite expensive; and you need a flexible curriculum because you have got to find the time to do the thing. At the end of the day I am a great fan of it and I want to see the resource for that but I would say that bad practical work is worse than none. That is a slightly contentious remark for me to close on.

**Q142 Baroness Platt of Writtle:** I used to be the Chairman of Education in Essex and my recollection is that we had a career structure for technicians—T1, T2, T3 and T4—so that they could see during their lifetime they would have increases in salary. Is that common or not?

*Dr Osborne:* I do not think it is national.

**Q143 Baroness Platt of Writtle:** Might that be a good idea?

*Professor Taylor:* I would say ask the ASE; they will know exactly these things.

*Dr Assinder:* Could I just make a comment on safety issues because biosciences are not exempt from health and safety issues, particularly in things like microbiology which does cause great concern to teachers. One of the ways that is being addressed is through learned societies, for example the Society for General Microbiology which provides health and safety guidance and runs practical training courses for teachers. The key to this, as my colleague mentioned, is to produce exemplar practicals that have been risk assessed that are not followed step-by-step but are open-ended so that teachers can inspire the students with what they can learn through investigation.

**Chairman:** Alright, thank you very much indeed all of you. I think it has been an extremely useful session and we value the time that you have given to us. As I said to the previous group, anything you feel you want to say to us that you think of subsequently, please write to us. Thank you very much indeed.

### Supplementary Evidence from the Royal Society of Chemistry

Following the submissions of our written and oral evidence the Royal Society of Chemistry would wish to make the following further points:

#### 1. OFSTED SUBJECT REPORTS

We have serious concerns that the new regime for subject inspections, which is admitted by Ofsted itself to be not statistically significant, will mean that important conclusions from the previous rich bank of data will be unable to be made. Thus conclusions on the quality of teaching and pupil achievement and their relationship to the teachers' subject qualification, the amount of practical work, the standards of laboratory accommodation, etc will be unable to be made and progress, or lack of it, monitored.

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## 2. INTERACTIONS BETWEEN SCHOOLS, HIGHER EDUCATION AND INDUSTRY

There can be little doubt that factors such as a charismatic, lively teacher, good role models, and good careers advice are factors that influence young people's choice of further study and possible careers. The RSC has been concerned both with the low transfer rate into higher education in the chemical sciences from those studying A-level chemistry and the even lower transfer rate from those socio-economic and ethnic groups for whom entry to higher education is not the norm. As a consequence the RSC has secured funds from the Higher Education Funding Council for England (HEFCE) initially for a pilot project between schools, HE and industry in three regions to address these issues. This project Chemistry: The Next Generation (C:TNG) is now being rolled out in a further three regions and has become part of the Chemistry for our Future (CFOF) project (also funded by HEFCE) to ensure the future sustainability of strategically important but vulnerable university subjects. Further details can be found at [www.rsc.org/CFOF](http://www.rsc.org/CFOF) and [www.rsc.org/Outreach](http://www.rsc.org/Outreach).

*July 2006*

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THURSDAY 13 JULY 2006

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Present	Broers, L (Chairman) Howie of Troon, L Mitchell, L Paul, L Perry of Southwark, B	Platt of Writtle, B Selborne, Earl of Sharp of Guildford, B Sutherland of Houndwood, L Taverne, L
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### Memorandum by the National Union of Teachers

#### INTRODUCTION

1. The National Union of Teachers welcomes the opportunity to contribute to this call for evidence into science teaching in schools from the House of Lords Science and Technology Select Committee.

#### RETENTION AND RECRUITMENT ISSUES

2. Research undertaken by the NFER (2004–05), commissioned by the DFES, found that, *“for the science teaching population there is a large imbalance in the representation of school sciences. In total, 44 per cent of all teachers who taught science have a specialism in biology compared with 25 per cent who are chemistry specialists and 19 per cent who are physics”*.

3. There should be a balance of expertise in science teaching, particularly since, in the past two decades, targets for recruitment to science teaching have only been met in three years (1991–93) in the last 25 years. The allocation of science places at graduate level has been uneven, with the majority going to biology and combined science. There are insufficient recruits for the teaching of chemistry and physics.

4. The Secondary Schools Curriculum and Staffing Data has not been sufficiently robust to draw significant conclusions on staffing for science. The survey does not make distinctions about individual science subject expertise, but amalgamates data into the broader subject science areas. This does not give an accurate picture of the recruitment crisis.

5. Difficulties of teacher supply have impacted markedly upon science education. The shortage of science teachers has led to a significant lack of match with teachers teaching individual disciplines in which they do not hold a specialism.

6. The NUT welcomes the Government’s “Science Innovation Investment Framework 2004–14”. The funding should support the Government’s “next steps” initiative for increasing the supply of science, technology, engineering, and mathematics by focusing on:

- achieving year-on-year increases in the number of young people taking A levels in physics, chemistry and mathematics, including making science a priority in schools by including science in the School Accountability Framework;
- stepping up the recruitment shortfall regarding the training and retention of physics, chemistry and mathematics specialist teachers;
- continuing the drive to recruit science graduates into teaching via Employment-Based Routes and giving new incentives to providers of £1,000 per recruit to attract more physics and chemistry teachers; and
- developing and piloting a Continuing Professional Development programme leading to an accredited diploma to give existing science teachers without a physics and chemistry specialism the necessary subject knowledge and pedagogy they need to teach these subjects effectively;
- offering additional courses to enhance physics, chemistry and mathematics subject skills for those entering teaching who do not have a recent degree in the subject from 2006;
- improving the recruitment and retention of science teachers, for example, by increased “Golden Hellos”; and
- expanding the student associates scheme to give science and mathematics students at university a taste of teaching with a view to encourage them to pursue teaching as a career.

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7. It should be a matter of serious concern to the Government also that science teachers are moving to the Independent Sector where they are more likely to specialise in a particular science field.
8. The NUT welcomes the fact that the Government has in place a recruitment programme to retrain and retain physics, chemistry and mathematics specialist teachers.
9. It is important that the Government works in partnership with key stakeholders including employers, universities, science centres, learned societies and Research Councils, to demonstrate to young people the range of the inspiring opportunities that studying science can lead to. One such initiative is a Science and Engineering Ambassadors Scheme which places role models in businesses in schools. There are 12,000 Science and Engineering Ambassadors across the UK representing over 700 different employers from a large range of multinationals and other organisations such as the NHS and the Environment Agency. On average each ambassador works with schools on two to three occasions per year.
10. Science teachers need to be supported fully by appropriately trained and skilled technical support staff. The issue of recruitment and retention of such staff must be evaluated in terms of salary, conditions of service, professional development opportunities and opportunities for career progression. This should include all appropriate interested parties and take place as part of a wider review of the role of non-teaching staff in schools.
11. The NUT welcomes also the Government's commitment to producing guidance on the use of financial incentives to encourage schools and Higher Education Institutes to share resources and expertise with other schools in a given area. From 2006, the Secondary Strategy and Specialist Schools and Academies Trusts will identify and systemise models for effective collaborative working and distribute these among schools. It is important that such initiatives are evaluated properly and feedback given to schools and other stakeholders involved.
12. The NUT will monitor the Government's intention to improve the state of school science accommodation in schools. There has been inadequate investment in this area which has led to much equipment becoming obsolete with fewer technicians available.
13. Funding needs to be specifically earmarked, however, to improve the quality of science laboratories rather than just reviewing the Building Schools for the Future exemplar designs for school labs, to ensure they reflect the latest thinking of what is required to ensure effective science teaching.
14. Fewer women than men train or pursue careers in science and technology. It is important that gender data from these industries need to be made available and visible so that any inequalities in the system can be addressed. Industry and business leaders need to be involved in developing measures to tackle gender imbalance. The NUT welcomes the fact that the Government has invested £1.5 million for work to be involved in initiatives such as setting up a resource centre targeted at women scientists and engineers.

#### THE SCIENCE CURRICULUM

15. The NUT will monitor the new Key Stage 4 14–16 curriculum and the introduction of the new science GCSEs. The policy priority must be to re-evaluate the effectiveness of these changes and ensure that these changes inspire an improved science curriculum. The NUT welcomes the intention of Government's instruction to the QCA to seek advice from independent scientists on how the new Key Stage 3 science programme of study can stretch the most able. Providing additional training and guidance for teachers to deliver the new science Key Stage 4 programme of studies and GCSEs must be a priority for the Government.
16. The new core science GCSE will run alongside a second GCSE in additional science. Assessment will now include a multiple choice response. Since these new core science examinations are the first major GCSEs where pupils will have the option of sitting some tests automatically, it is important that they are evaluated by the Regulator to ensure that students are being taught a wide range of scientific, technical and mathematical languages.
17. While it is the intention of Government to increase provision for students to study the three separate science GCSEs in schools, by 2008, the NUT would wish to know how this will be carried out. There is no detail outlined in the Science and Innovation Investment Framework about how this is to be achieved apart from schools being encouraged to work collaboratively with other schools, FE colleges and universities and encouraging all schools to make triple science available to all pupils who can benefit from these.

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18. Alongside other subjects, science learning can be restricted to “teaching to the test”, driven by the pressures of Key Stage 3 National Curriculum tests. In addition, it is important to evaluate how coursework is assessed in GCSE science with the aim of encouraging more engaging practical work in schools. Practical work needs also to be reviewed to assess how far it is constrained by health and safety regulations.

19. The NUT supports the initiative to consider links between the science curriculum and other relevant National Curriculum subject areas. There should be a broader view of the curriculum. The Citizenship and PHSE curricular, for example, could make available, opportunities to build on students’ entitlement to science education and to build upon “scientific literacy” or “science for citizenship”, through the consideration of the impact and social and ethical implications of scientific developments and practice, such as human embryology, cloning or genetic engineering.

#### OTHER ISSUES

20. There is also a concern expressed by the science teaching community that pupil behaviour is a major disincentive to students who decide not to enter the teaching profession. This impacts also on the retention of science teachers in schools.

21. There are important health and safety implications surrounding science education also. Not least of these, is the issue of class size where practical work is taking place. The NUT endorses the House of Commons’ Science and Technology Committee report (2002), which stated that consideration be given to the establishment of a nationally agreed and enforced upper class size limit for practical science lessons, which are both realistic and manageable. Many laboratories have been designed to accommodate 21 individuals and class sizes for practical activities should be appropriate to these circumstances. The Committee recommended that in the longer term, the aim should be to reduce secondary school practical science classes to no more than 20 students.

22. As the new information, advice and guidance system reverts back to schools, it is important for the Government monitors how key stakeholders will develop ways to improve the awareness of young people and their parents and teachers, of the benefits of studying science and the career opportunities available to those with science, engineering and maths degrees and other related qualifications.

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#### Examination of Witnesses

Witnesses: MR JOHN BANGS, Assistant Secretary (Education and Equal Opportunities), National Union of Teachers, MS ELSPETH FARRAR, Director, Careers Advisory Service, Imperial College London, and MS MARIE-NOËLLE BARTON, Director, Women into Science, Engineering and Construction (WISE), examined.

**Q144 Chairman:** Thank you, Ms Barton, Mr Bangs and Ms Farrar, for coming to talk to us. This is our final evidence session in this short inquiry into science teaching in schools. I welcome all the others who have come to join us. I think you probably know that there is an information note on the inquiry if you wish to get it. I think, first of all, we would like you to introduce yourselves, please, and, if you wish, to make an opening statement. If you do not, then we will go straight into questions. Perhaps we can start with you, Ms Barton.

*Ms Barton:* My name is Marie-Noëlle Barton, and I run the Women into Science, Engineering and Construction campaign.

*Mr Bangs:* I am John Bangs. I am the Assistant Secretary (Education and Equal Opportunities) for the National Union of Teachers. I would like to make a very short statement.

*Ms Farrar:* I am Elspeth Farrar. I am the Director of the Careers Advisory Service at Imperial College and one of the Board of Directors for AGCAS (the Association of Graduate Careers Advisory Services).

**Q145 Chairman:** You say you wish to make an opening statement.

*Mr Bangs:* Yes, thank you, Lord Chairman. It is only to draw the Committee’s attention (and that is why I think the Committee’s inquiry is extremely timely) to the fact that the School Teachers’ Review Body has asked two questions on exactly the issue that you are investigating as well and, therefore, the evidence from the statutory consultees to the School Teachers’ Review Body could be cross-referred to you and you may find it very helpful.

**Q146 Chairman:** Thank you for that input. Let us go to the questions. Do you feel that the careers advice offered to students by teachers or dedicated careers advisers when they select their A level subjects is adequate; and to what extent are school students thinking early enough about the excellent career prospects which can follow from science and mathematics qualifications? Ms Farrar, perhaps you would like to start.

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*Ms Farrar:* Generally, I think that probably the advice that is being given to the more able students in schools now, particularly those that are staying on to do A levels and thinking about carrying on into university, is not as good as it has been in the past, and I think this is as a result of the move to the Connexions Service which very much has its priorities around the less able students. As a result, since the introduction of the Connexions Service, many of the more able students in schools have not had the support and advice that they would probably have had in the past. I think this has had some effect on their guidance on going into university, their choice of subjects and maybe not having as much of a scope or a breadth of ideas about what they could go on and study as they maybe had in the past.

*Ms Barton:* I would like to endorse what has just been said, and I would go further and say it is almost now a stigma for young people to go and see a careers advisers from the Connexions Service, because they deal mainly with young people who have got drugs problems and so on, although I want to say things are very good with Careers Scotland. I think this is an English problem. The other problem that there is with careers advisers is that the Institute of Physics did a survey last year and found that 90 per cent of careers advisers said that they did not feel confident with giving advice about science and engineering careers, so we have a real problem there, and again, the same survey from the Institute of Physics found that there was no careers adviser who had a background in physics. As for the careers teachers, very often there is no training given to careers teachers, and so they struggle. That is the answer to the first part of the question.

*Ms Farrar:* Could I just interject. I think you are talking mainly about careers advisers working in schools. I know many who are very able at giving advice on science and engineering careers in the higher education sector. It may be that the Institute of Physics is looking only at schools.

**Q147 Chairman:** The trouble is it is a bit too late.

*Ms Farrar:* Yes, I know.

**Q148 Lord Mitchell:** This is a question totally deriving from my ignorance. How are careers teachers or advisers trained in schools?

*Ms Farrar:* They are mostly all graduates from a very wide variety of different disciplines and the vast majority would then go on and do a one-year post-graduate qualification in vocational guidance, followed by an induction year; so in many ways the training for careers advisers is very similar to the training for teachers in its structure.

**Q149 Lord Mitchell:** But they would not be people who had been out into the big wide world?

*Ms Farrar:* Many do go and work first and then come back into careers work at a later stage having had some experience in the industry; less so probably within a school base, particularly now because of the Connexions Service. Of course, personal advisers are not all graduates—they do not have to be graduates—whereas in the past careers advisers traditionally were graduates before going on to do their post-graduate careers advisor training.

**Q150 Chairman:** Mr Bangs, in your evidence you mentioned the Science and Engineering Ambassadors Scheme whereby people with STEM backgrounds go into schools to inspire school students in these subjects. Are there ways in which we could enhance that programme?

*Ms Bangs:* I think there are. I think there is a central fault in that the national strategies, particularly in primary, have concentrated on literacy and numeracy, and then there is not the concentration on the various branches of science. In fact, a local authority I know very well relies on the Gatsby Foundation to provide its science advisers, and they actually provide the most stimulating advice to schools and act as enthusiasts, but the fact that schools are reliant on a private foundation to give them something which I personally believe ought to be part of the Government professional development initiative is something which I find problematic. That is not a criticism to the Gatsby Foundation. Teachers appreciate that very much.

**Q151 Baroness Sharp of Guildford:** This is really to Ms Barton. What do you see as being the key reasons behind the relatively low number of girls opting to take physics A level and going on to do physics degrees? Do you think it is to do with a lack of female role models, and what do you think are the answers to these problems? Can I add a rider to that: is there a danger that we are going to see a disproportionate number, amongst the girls who do go on to university, perhaps coming from the girls' private schools rather than from the state school sector, and is there a danger of skewing numbers in that direction?

*Ms Barton:* Let me answer the first part of the question. I think the bottle-neck is between GCSEs and A levels, because once they have committed themselves to A levels they often then take an undergraduate degree course. The main problem is the perception of the subject of physics. It is perceived by young people, it is perceived by a lot of teachers (and I am not talking about the science teachers but other teachers), it is perceived by the parents as being a difficult subject. You need maths and people say it is a hard subject compared to biology, for instance. That is the perception; I am not saying it is or it is not. So, there is a need to change the school culture, but



also the teaching of physics is not always what we call “girl-friendly”. We find that girls are particularly sensitive to what happens in the classroom—the classroom experience is important to them—so if the examples that the teacher uses are boy orientated, then the girl will switch-off. It is quite easy for teachers to find examples which are gender free. If you talk about the wheels of a car, you could also talk about the wheels of a pram—that is men and women—but you could talk about the wheels of a bicycle, which is gender-free. That is the sort of example. The other problem is that there is now a huge array of A levels available and a lot of young people choose what they call the “funky” subject—media studies and so on. They have not yet seen whether there are careers opportunities long-term, but they go for the new subjects rather than the traditional subjects. So, these are the reasons.

**Q152 Lord Mitchell:** It is a question I have raised with other people giving evidence, but it seems to me that in this 21st century that we are in there are many “funky” (your word) but exciting new jobs. If you just look at maths and you look at the City of London and you look at working for Google, it is not the image that maths would have had ten or fifteen years ago. I am surprised that it has not filtered down that there are tremendous new opportunities in the new industries and new opportunities out there. I just wondered if it is something we ought to think about.

*Ms Barton:* There is certainly a lot which needs to be done on the promotional side of physics and all the careers available which use physics. We need more role models. Dealing with the second part of your question, which was the problem of the lack of role models, certainly that is an issue. When you look at TV, for instance, there was recently some reporting about the Mars Project. All the people who were interviewed were men and here was an opportunity which was missed, although the Institute of Physics tells me that a lot of the physics teachers are women, so at least there are role models in schools, but “role models” are quite important. How can the problem be addressed? As you know, an interesting experiment in some schools is single-sex teaching. I have not said single-sex schools, I have said single-sex classes for subjects like technology and science, and some schools find that girls perform much better when they are taught in groups of girls. So, that is an interesting experiment. Getting role models in schools, having promotional brochures which show physics and how physics is part of their every day life would help tremendously.

**Q153 Baroness Sharp of Guildford:** The private state school split?

*Ms Barton:* I do not have lot of information about that, so I cannot answer that question.

**Q154 Baroness Sharp of Guildford:** Does doing three sciences at GCSE instead of doing the combined sciences make a difference?

*Ms Barton:* The Institute of Physics tell me that the young people who tend to take the three sciences tend to take it because they want to go into either medicine or veterinary surgery. They do not really use the physics *per se*.

**Q155 Baroness Sharp of Guildford:** How about international comparisons? We know that for science as a whole the dip that we see is one that is mirrored elsewhere. What about with women? Is this the same elsewhere?

*Ms Barton:* That is a big question, because cultures are so different. In this country we have a problem about stereotyping between men and women but we also have a problem about stereotyping with engineering and science. If we compare that with other countries, we do not always have the same stereotype. You have worked out from my accent that I come from France. In France engineering is perceived quite differently, so it is not always easy to compare the two.

**Q156 Lord Taverne:** Do you think that the new curriculum, which is going to relate the teaching of science much more to the experience of the children and make it more interesting, might make a difference in the way in which the teaching of physics will appeal to girls?

*Ms Barton:* As long as we keep the rigour of what they have to learn in order to get good quality qualifications, then anything which is going to make it more interesting and more relevant to their life has to be welcomed, but we need to keep the rigour.

**Q157 Lord Sutherland of Houndwood:** I would like to talk a little bit about teaching as a career. I wonder initially if I could ask Elspeth Farrar about the attitude of undergraduates. Do they see advantages, disadvantages in this as a career and (a subject we have already touched on) is there a wide enough range of career advisers who have the relevant background to help on this matter?

*Ms Farrar:* To cover the question on advisers, first of all, I think careers advisers in universities are very well briefed about teaching as a potential career for all areas of teaching. It is one of the stock areas that any adviser would be able to advise on. As far as students’ attitudes towards teaching, first of all, I would say this is not just from an Imperial perspective. I have sought the opinions of other directors of career services around the country, because one of the very difficult things about careers guidance is that you very often do not have any hard and fast evidence because of the confidentiality of interviews. But the anecdotal view is that, first of all,

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students from science, technology and engineering backgrounds are so heavily sought after by such a very broad array of companies and organisations that very often teaching just does not really feature on their radar at all. Many students that are doing particularly the physical sciences and engineering disciplines can attract very high starting salaries, much higher than the starting salaries that are available through teaching. The average starting salary for Imperial graduates who graduated in 2005 was £26,000, and that is the average. It is not just the starting salaries, it is the progression. Many of those students will go on to careers where they are earning six figure salaries very swiftly within their careers, and that is a very tough nut for teaching to crack. There is also an issue to do with status. Many of the students do not see teaching as having enough status for them. They are very often looking for career areas which have a very clear professional status and a very clear recognition, either through rewards or through social profile, and I think teaching has lost the status that it once had. That is partly because of perhaps the poor media image of education at the moment. Education is constantly in the media, and not always for very positive reasons. As a result, there are a lot of negative messages coming across about what it would be like to work in education, what it would be like to be a teacher, and that comes across to the students. Often academics do not encourage their students to go into teaching, they would prefer them to stay within their subject area, they would prefer them to stay on and do research or go into industry, and often parents also are reluctant to encourage students to go into teaching. The other thing that we have noticed is that there has been a move away from public sector careers generally—I do not think it is just teaching—but whereas in the past you can imagine that graduates from universities, particularly the traditional universities, would have been the kind of stock for many of the public sector careers, including the Civil Service and teaching, in the last five to ten years there has been a distinct move away from an interest in those areas and more of an interest into industry and commerce and the benefits that that can bring. On the benefits, they do see the traditional benefits, the long holidays, there are some that see the sense of social service and social engagement, but those are few and far between, particularly within the science and engineering students.

**Q158 Lord Sutherland of Houndwood:** Some of the reasons you have given for students not being attracted to science are generic and some of them are specific, I wonder if I could ask the other two whether they wanted to comment on whether there are additional disincentives that might explain the high vacancy rates?

*Ms Barton:* Yes. I absolutely confirm and agree with everything said, but there are a couple of things that I want to add. Many students say to us, “If we go into teaching, once we become a really good teacher and we get promoted, we are out of the classroom, we are into admin work, we are into management work and, therefore, what is the point of joining a profession to teach and then end up being a manager?” The other issue is the issue of discipline. We really feel that it is hard work to deal with the discipline of young people in secondary schools particularly. It is a big turn off.

**Q159 Lord Sutherland of Houndwood:** These are common to all areas of teaching. Are there any specifics in science?

*Mr Bangs:* There are a number of issues I would like to pick up. The first is that actually there are opportunities within teaching for teachers to develop their subject skills and knowledge in science, with whatever branch (biology, chemistry or physics), and the Advanced Skills Teacher Scheme does actually provide that opportunity. I am actually, incidentally, concerned about the future of the AST Scheme. We have reservations about the AST Scheme, but, nevertheless, the evidence is that it has given classroom teachers a career route and provides a real opportunity in terms of sciences.

**Q160 Lord Sutherland of Houndwood:** The AST Scheme; I am sorry?

*Mr Bangs:* I am sorry, Advanced Skills Teachers. The second is that we did a survey with what was then the Teacher Training Agency about four or five years back surveying sixth-formers on what they wanted out of teaching, whether they had considered it, and the highest percentage in terms of reasons was to do with making a difference to children’s lives. So, I do not think we should underestimate the importance of the social commitment and the educational commitment reason that youngsters have. That brings us on to: are teachers encouraging youngsters to go into teaching who may be interested in science? I actually come back to something which I believe is far more problematic than all the other reasons, and I have some real reservations about the issue of role models by the way. That is that, quite simply, there are not enough graduates (particularly with physics and chemistry degrees) coming out of universities. That is the core problem. *Ergo*, there are not enough graduates with physics and chemistry degrees going into teaching at all, and you can source it right back to that position. In a sense, in a lot of schools you might get a match where you are actually teaching chemistry and physics, and there is evidence to show that there is a very high rate of match between those degrees and what you are teaching, but this still is not enough. It is very small indeed. So, I tend to think what there has to be an is an enormous concentration

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by government on the core source of the problem, which is increasing the teaching capacity of higher education institutions, focusing on science and actually concentrating on using all your resources to do that, then linking that up with schools and identifying a career route for youngsters who may go into teaching in that way. All the other things about disincentives pale into insignificance compared with that, it seems to me.

**Q161 Lord Sutherland of Houndwood:** One senior mathematician did a calculation a few years ago in which he worked out that if everyone who got a high quality degree in maths went into maths teaching there would still be a shortage?

*Mr Bangs:* Yes.

**Q162 Lord Sutherland of Houndwood:** I just want to come back to some of the other issues, particularly pay. There are shortage areas, like physics and chemistry, but what are your views on whether or not additional pay (a) would help and (b) would be acceptable to the profession?

*Mr Bangs:* I know that the Government has concentrated very, very hard on “golden hellos” and “golden handcuffs” and bursarial inducements to the tune of £6,000 for “golden hellos” and £9,000 for bursarial sums. There is evidence that that has a short-term impact, but only a short-term impact. What happens is that after two or three years the attractions of a career outside school become overwhelming and the incentive that you originally had to go in disappears, so they only have a short-term impact.

**Q163 Lord Sutherland of Houndwood:** Are there any numbers on that? Is there a study of evidence on that?

*Mr Bangs:* There is quite a lot of evidence that was given to the Review Body, giving the footnotes and references to that, and we will give that to you.

*Ms Farrar:* Lord Chairman, can I talk about physics particularly. I have the figures from last year’s graduates and where they have gone on to. For physics, 4.1 per cent of all physics graduates went directly into PGCEs and 8.4 went direct into teaching through the various direct entry teaching schemes, which is quite a lot higher than the average across all degree areas. So, quite a lot are going into teaching, but there are just not that many in numbers.

**Q164 Lord Mitchell:** PGCEs?

*Ms Farrar:* Post Graduate Certificate of Education.

**Q165 Lord Taverne:** Could you explain all the acronyms, please?

*Ms Farrar:* So a relatively high proportion of physics graduates are going into teaching through one route or another in comparison to overall graduates, but the numbers are still low.

**Q166 Lord Howie of Troon:** Can I ask a very quick question? Mention has been made of people going out of teaching into other careers, sometimes into management or sometimes into other careers altogether, but is not this fairly commonplace throughout the economy? People like me have had three careers; I ended up here!

*Ms Farrar:* I think many students throughout their lives will have several careers, and actually one of the fears that they may have about going into teaching is that they will go into teaching and stay a teacher forever. I think if we can get across the idea that they can move out of teaching into something else and then possibly move back into it, that could be quite an incentive compared to the idea that you are going to be in school-based teaching forever; so some kind of promotion of maybe sabbaticals out into industry for experienced teachers would be quite useful.

**Q167 Baroness Sharp of Guildford:** I wondered whether you at Imperial had any experience of Teach First and how that had been received?

*Ms Farrar:* Yes, we work very closely with the Teach First organisation, and that has been a very successful way of encouraging students to experience teaching, committing to doing two years of teaching, but also then knowing that there are various companies who will still consider them for a graduate training programme—investment banking, engineering, et cetera—so that has worked very well, and at Imperial we have always had a fairly high proportion of students that have gone into the Teacher First programme, which I think was started about three or four years ago, and on average nationally they recruit up to about 250 students.

**Q168 Baroness Sharp of Guildford:** I think it is quite competitive getting into it.

*Ms Farrar:* It is very competitive. They only recruit very high achieving science and technology students into teaching.

**Q169 Baroness Perry of Southwark:** You said earlier that you thought that the trend away from going into teaching was part of a bigger trend of good graduates going away from the public services. Do you have any figures on that?

*Ms Farrar:* I do not, I am afraid, but there has been a feeling that there has been less interest in the traditional public sector areas like the Civil Service and teaching particularly from science and engineering students.

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**Q170 Baroness Perry of Southwark:** Are there common reasons across public services for people saying that? Are we looking at the wrong question when we look at why just not teaching?

*Ms Farrar:* Particularly for the physical sciences and engineering I think there is just so much competition to recruit them. They have a very wide choice. I also feel that there is a tendency on the part of students to look at immediate gains and immediate benefits over possibly longer term career objectives. I think that has been the case up until recently. I also would counter that by saying that we are just beginning to get a feel that students are looking now at work/life balance as well, so maybe that is beginning to swing the other way, which would be good. Unfortunately, there are no figures.

**Q171 Chairman:** You did give us some useful figures there. Were they from Imperial?

*Ms Farrar:* No, those are national. Every year universities do what is called a first destination survey.

**Q172 Chairman:** I would like to rephrase Lord Sutherland's question more bluntly. Universities had to face this issue with senior academic staff and the appointment of professors. There is now a very strong market influence. If you are in sciences or engineering, professors will just be offered more money. Is that not necessary for teachers? I do not mean just at the beginning; I mean across the board, continuously.

*Mr Bangs:* In general, there are arguments about whether or not the relativities are maintained with the other jobs in the private sector and also the other professions. We tend to think they are not but, to put that to one side, Elspeth is talking about the attractiveness of teaching if it is short term and going back to industry. All the school improvement evidence is that retention and stability for children with teachers is a very, very important issue, so there is a real tension between the two issues. The evidence that we have—I am not sure about the phrase “work/life balance” but nevertheless it is a useful summary—is that if teachers feel professionally and creatively fulfilled they will remain. Although money is important and it should not become a pinch point and stop you doing things you wish to do reasonably and normally, being able to have a career which recognises your skills and, for instance, involves you in moving to other schools, being involved in professional development, having the creative site to conduct your own research and investigations, having a relationship with a university or a business outside school while you are continuing to teach, that kind of wider penumbra of creativity around you is feeding you as a person as well as you as a teacher. If that is in place, you are going to stay and remain

motivated and committed. Our argument is, to be honest, I wish the government had concentrated on that rather than the other things it has been concentrating on in recent years. The professional development and the performance development of teachers is very patchy and it is even more patchy when it comes to science teachers.

**Q173 Lord Howie of Troon:** Is that not the kind of answer we would expect, not from somebody who wished to induce more science teachers, but from a trade unionist who is a leveller?

*Mr Bangs:* I do not believe that is a leveller. The main objective for teachers is to have children reaching their full capacity in terms of achievement. That same objective should apply to all teachers as well. That is not a leveller argument; it is about getting the best out of teachers. Elspeth's point about how you maintain a relationship between highly committed, highly skilled people, scientists, and with schools is something we need to tackle. There is a real lack of imagination about how that is done. You only have to go back to the James Report of 1971 where it says that every teacher should have a year off once every seven years to conduct their own research. That was a report which was bought into by the then Conservative Government but very little happened over the oncoming years. We need a professional development strategy which concentrates on the subject based skills of teachers, particularly science because that is where the shortages are but for everyone else as well, and we need something that understands that teachers need personally fulfilling so that they can take time out from a very long, hard career to recharge their batteries professionally. It is as simple as that.

**Q174 Lord Howie of Troon:** Your answer to the question should science teachers be paid more than other teachers is no?

*Mr Bangs:* I think all teachers should be paid the same levels of works. Additional financial incentives only have a short term effect. That is the evidence and I said I would give that to the Committee. There is research on that.

*Ms Farrar:* On the continuing professional development area, I think that is also a particular anxiety for physical science and engineering students who are very much engaged with their subject area. There is a fear that they are going to lose their skill. If more was made at the entry point to teaching with more publicity about CPD schemes for teachers and the possibility of doing part time courses or a part time PhD while teaching, that would be an incentive to students.

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**Q175 Earl of Selborne:** I would like to ask about the Student Associates Scheme whereby science and mathematics undergraduates are given a taste of teaching. Is it successful? Could it be expanded and improved?

*Ms Farrar:* For my part, the students that I have spoken to that have been on those schemes have generally found them very interesting and very useful. A reasonable proportion are carrying on to apply to do a postgraduate certificate in education. Where it does not work is if they get a negative experience on the Student Associates Scheme. The schools that are involved, the teachers that are involved, need to be picked very carefully. Otherwise it can have a detrimental effect. Along with the Student Associates Scheme there are others like the Teach First Scheme. At Imperial we run a scheme called Inspire which is specifically to encourage post-doctoral staff to go into schools and work as teachers. We have been running that scheme for quite some time with some success as well. It is much smaller than the Student Associates Scheme. One of the problems with the Student Associates Scheme is it is not available evenly across the country and there are some areas where it is just not operating at all.

**Q176 Earl of Selborne:** What could be done to make it operate in those areas where it is not effective?

*Ms Farrar:* I am not sure why it is not operating universally. I do not know whether it is something to do with education authorities in particular areas but, as far as I am aware, there are no teaching associate schemes available in the West Midlands, which is a large area.

**Q177 Lord Mitchell:** How can barriers facing professionals who have a background in science and maths who want to become teachers after having pursued a successful career in the field be addressed? I sense there are a lot of people out there, perhaps in their forties, fifties or even sixties, who would get tremendous benefit from working in this sector and would really want to do it, having had previous careers. I would like to know how easy it would be for them to come into this.

*Ms Barton:* It is the pay issue.

**Q178 Lord Mitchell:** I think there are a lot of people who are not bothered by pay. They may have come to a certain point in their careers where they do not want to consider pay; they want to give something back. I personally know lots of people like that.

*Ms Barton:* Some will be concerned about a pay cut and the fact that good teachers get promoted and go into admin work. The amount of admin work for every single teacher and the discipline we have talked about. We have talked about the issues and unfortunately they are the same.

*Ms Farrar:* There is also the lack of recognition of their experience. To go into teaching having had a very successful career somewhere else and maybe having got to a very senior position, if you then choose to go into teaching you are going to have to go into school probably on a school based training programme as an unqualified teacher earning £14,500.

**Q179 Lord Mitchell:** I know that is the way it is. I just have a serious problem with it. If I at 63 years old wanted to spend two years of my life teaching economics which I am reasonably qualified to do, would I be able to do it at my local comprehensive?

*Ms Farrar:* You would have to apply for a school based teaching training position or teaching assistant post. You could do it, it is feasible.

**Q180 Lord Mitchell:** How about the headmaster of Westminster School two years ago who, having retired, could not get a job teaching maths?

*Mr Bangs:* He was not a qualified teacher.

*Ms Farrar:* Many students and other people will choose to go into the private sector because they do not necessarily need teaching qualifications, or QTS.

*The Committee suspended from 4.21 pm to 4.29 pm for a division in the House*

**Q181 Chairman:** Did you want to add anything, Mr Bangs?

*Mr Bangs:* The graduate teacher and the registered teacher schemes are one of the best things that have been introduced over the last few years. That does not mean to say I think they are perfect. The nut that has not been cracked—and we have done some research on it—is the self-efficacy of those who are on graduate and registered teacher schemes. Often they do not get the quality mentoring that they are supposed to get. Student teachers who are attached to higher education institutions and who get proper support away from the school have a much higher regard for themselves than adults who come in with a commitment, who want to make a difference and have a change in career. Nevertheless, as an idea and a concept, it is an extremely important one. I agree with you. There is a whole raft of mature adults out there who really do want to make a difference and need all the incentives to do that with a school. You asked whether someone aged 63 could come back. I say unequivocally yes. I think people should go back whatever their age if they have something to contribute. The issue however is the one of qualified teacher status. That does not mean to say that there are not others who come in and help support teaching. They can be teaching assistants, for example, and help support teachers that way. The barriers are that we do not yet have as effective and as

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properly functioning a graduate registered teachers' scheme as we might have.

**Q182 Lord Taverne:** Is there not a case for relaxing the teacher training requirements in the case of somebody in a senior position in industry who has some natural authority and does not perhaps have to be trained to control a class? If they have to go back to school, as it were, and become a teacher again, is there not a case for relaxing it?

*Ms Farrar:* I do not think you necessarily have to relax it. What you might do is have an accelerated scheme where they can gain the QTS quickly. There are schemes available, for instance, for qualified teachers from other countries who want to gain the QTS to enable them to teach in this country. They go through an accelerated scheme in order to gain qualified teacher status. For somebody who has a lot of professional experience in industry or commerce, maybe there could be some kind of accelerated scheme.

**Q183 Lord Mitchell:** If we do not have enough teachers in the science subjects—clearly we are saying we do not—and if to change the amounts coming from normal sources would take a long time, it seems to me we have to look elsewhere. We have to be creative.

*Mr Bangs:* The routes and the flexibility are there. They just could be improved. I had a look at the recruitment figures to teacher training courses every year. There has been a major improvement in recruitment across the piece. There are still specific shortages but they are not as great as they used to be. The major issue from the schools' point of view is still one of retention in some areas. I know there are percentages about numbers coming in, in terms of physics and chemistry but they are still a massive shortfall. I still think the issue is one of shortfall allied to the issue of have we done enough to attract adults from industry to come into teaching. What routes currently could be improved. My view is that the graduate and registered teacher route is still a relatively under-resourced, under-cared for route, but it is still the right route. It needs good attention.

**Q184 Lord Howie of Troon:** Could you have something analogous to a visiting professor?

*Mr Bangs:* Yes. In terms of my own past history, I taught in a special school for a long time in east London and I had four artists in school. I absolutely think you should have scientists in schools. Those kinds of schemes are enormously creative and we should encourage them.

**Q185 Lord Mitchell:** Ms Barton, how difficult do you think it would be for mothers with backgrounds in science and maths, who take family time off or

whatever, to come back into schools? Is that easy or not?

*Ms Barton:* The responsibility of children falls on two people, men and women, obviously. Women still say that teaching is an excellent career for them if they want to combine a family and a job. There are the holidays and many other advantages as well. Yes, it is very attractive to women.

**Q186 Lord Howie of Troon:** Many teachers leave. Why? What are the main reasons for teachers leaving? What can be done to prevent them leaving? Is this more serious in science than in other subjects?

*Mr Bangs:* There is a bit of evidence, particularly in the area of communications technology. If you have really moved fast and you have done well in information communications technology you will be poached.

**Q187 Lord Howie of Troon:** You would get more money?

*Mr Bangs:* Absolutely. You are worth a lot to a private company producing software because you know what is going on in a school. You are very good at the technology and you can be a real driver because you are providing first hand all the time knowledge about what is needed in schools. You are very valuable.

**Q188 Lord Sutherland of Houndwood:** Is there a case for paying such teachers more?

*Mr Bangs:* I do think there is a case for paying all teachers more. We come back to the answer to a couple of questions back. There is a case for porosity between school and outside industry. You maintain an allegiance with school; you are part of the school structure but part of your career is out there working, whether it is in a higher education institution or whether it is with a company. That kind of flexibility seems to me the answer. What I think is so wrong is that when you lose people from teaching you lose them for a long time and utterly. There must be a way of twinning up.

**Q189 Lord Howie of Troon:** If teachers were seconded out to industry, would they be paid teachers' rates or industry rates?

*Mr Bangs:* There is an interesting question. I do not know. I would have thought it depends what you were doing. If you were learning, you would be paid teachers' rates; if you were doing the job in the industry you would be paid industry rates.

**Q190 Lord Howie of Troon:** You may not come back.

*Mr Bangs:* Maybe. It is a risk. The key drivers to teachers leaving the profession are fairly well documented. We did all the exit interviews when

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there was a real teacher crisis about two or three years back. It is the stress and the strain. You have a question on initiatives. I do not want to go into that particularly but there is stress and strain about initiatives over which you have little control. You can just about manage that but if you have a class or a group of children who are problematic and there is low level disruption from a group that will be the straw that breaks the camel's back. You will go. The trigger is pupil behaviour and that is fairly well documented.

*Ms Barton:* We are talking about leaving. I have been asked by the Institution of Physics to point out that there is also the natural leaving. The Institution of Physics tells me that the age profile of physics teachers tends to be in the fifties, compared with the age profile of teachers of biology which tends to be in the twenties and thirties. That is another group that we need to consider, the people who are going to retire. There is a real issue there as well.

**Q191 Baroness Platt of Writtle:** How satisfactory are the current arrangements with regard to subject specific CPD? Should there be a change of culture so that science and maths teachers are entitled or even required to undertake a certain amount of CPD every year?

*Mr Bangs:* I do not think that the arrangements for subject specific continuing professional development are satisfactory. In fact, Ofsted brought out a report yesterday on teachers' professional development which specifically criticised the lack of subject specific professional development and I agree with that. What has happened is that rightly the strategies are concentrated on literacy and numeracy. I would not want to take that away, but right through the system concentration has gone from the other subjects, from science, technology and the arts and humanities. From everything that we have done from our own professional development programme which we run, I think the lack of a funded national professional development strategy concentrating on specific disciplines is something that has been going on too long. The government in 1998, when it produced its Green Paper on teachers, mentioned the importance of that. It did have a professional development strategy in 2001. That went into the sand. The £92 million that went into it was very welcome but that does not exist any longer. The TDA does have the responsibility for coordinating a strategy but it is not funded. Whatever vehicle it is, whether it is a strategy or whatever, you simply cannot just rely on schools' individual decisions to meet national shortages. You have to have a national professional development strategy and a national subject based professional development strategy.

**Q192 Baroness Platt of Writtle:** You are saying you cannot leave it to the head?

*Mr Bangs:* The head plays a very important role but I think the head will not know where the professional development is. I despair a bit of local authorities, to be honest, who go on about their lack of capacity to do this, that and the other. They do have capacity which is all their staff. They should be proactively looking at where the best possible subject based professional development is, networking it and co-ordinating it with schools.

**Q193 Baroness Platt of Writtle:** The inspectorate ought to be doing that, ought they not?

*Mr Bangs:* I think they are specifically forbidden from doing so. They have to inspect and that is it, although they have just produced an interesting set of recommendations for professional development. We run our own professional development programme. There is a whole set of organisations like the two organisations represented here, subject based organisations, teacher organisations, who would give their eyeteeth as accountable national organisations to be the agents for delivering professional development. We can. Lots of other organisations can as well. The levers are there; they just have not been picked up.

**Q194 Baroness Platt of Writtle:** I did read your evidence and you are in favour of accredited diplomas, I understand, in recognition of CPD undertaken. How will this tie in with the new Excellent Teachers Scheme and should the two schemes be combined?

*Mr Bangs:* In terms of accreditation, we are not in favour of compulsory accreditation; we are in favour of optional accreditation. I think that is an important distinction. We are very much in favour of the General Teaching Council for England scheme which is to have a ladder of accreditation, which means that when you go on a professional development course or programme you do not have to do extra work on top of it, putting together all sorts of evidence. If you are a busy teacher, you just cannot do it. The new scheme run by the GTC is about recognising what you have contributed to the course and giving you points towards a higher qualification. What was the second part of your question?

**Q195 Baroness Platt of Writtle:** How would it tie in with the Excellent Teachers Scheme?

*Mr Bangs:* The Excellent Teachers Scheme has just been introduced. I do not want to go down this route particularly in terms of our critique of it. It has been introduced as a way of capping teachers' movement up the main scale and capping the costs. That is our view. I have been through the Excellent Teachers Scheme standards—so has our union—and offered

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evidence to the government on it. I think there is confusion between excellent teachers who are based in their own schools and advanced skills teachers who spend some of their time outside school, promoting what they understand and learn, their knowledge and understanding, to other schools. I would much prefer it if there was one form of advanced skills teacher who was not just tied to their school but gave their expertise to other schools. We have two parallel schemes running, the ASTs and the Excellent Teachers, and the only distinction that I can see is that one of them spends a lot of time outside school and the other one does not. I think the government needs to think again about how it rewards and identifies and encourages excellent teachers in the classroom because there is real overlap and confusion.

**Q196 Baroness Perry of Southwark:** You referred earlier to the large number of government initiatives as one of the pressures on teachers. Do you feel that they are being adversely affected? Is it one of the contributory factors to the problems of retention and, particularly, to what extent do you think the emphasis on constant testing within the national curriculum is having a negative impact on teachers' creativity?

*Mr Bangs:* I think it is. There is a set of reports that Cambridge University has done on a life in primary schools, a life in secondary schools and the costs of inclusion, the last part of the trilogy that was published in May. The evidence from primary is that at year six the amount of time spent on science drops massively because you are coaching youngsters at year six to get the highest possible grades in national curriculum tests for English and maths. At certain key points in youngsters' lives the testing regime, particularly at that wonderful time when you are 11, still up for it and you are not affected by all the trials and tribulations of being a teenager or necessarily affected, that is exactly the time when our teachers are really spending far too much time coaching for testing in English and mathematics. There is some very important evidence from the Assessment Review Group which shows that, for quite a lot of youngsters, particularly those who are not confident, that national curriculum testing makes them even less confident. There are lots of youngsters who are enormously confident and get testing under their

belts and become very skilled at answering test papers, but it tends to undermine the confidence of already unconfident youngsters. The bunching of initiatives? All I can say is that there is a bunching of initiatives. You will hear teachers from time to time saying, "For God's sake, give us a moratorium on government initiatives." The issue has always been—it is not a party political point—that if you have an initiative what you have to do is look at what is called embeddedness. That is: do teachers understand the need for it and do they own it? There have been government initiatives where teachers do own that. There is some very good work going on in citizenship, for example.

**Q197 Baroness Perry of Southwark:** Could you give us an example of both? If citizenship is a positive example, what is a negative example?

*Mr Bangs:* It is one of the crying shames of the literacy and numeracy strategies that every time teachers think they are about to own it—there have been phases—suddenly it is taken away from them. The government panicked, in my view, about the opposition's criticism of the lack of phonics during the election campaign and we had to change the national curriculum English because the government believed it had to ward off criticism that phonics were not being taught in schools when they were. All the history potentially of the literacy and numeracy strategies—it could be with science—is that teachers are desperate to own that. They believe it to be important and they have very good working relationships with consultants at local authority level. They could contribute an enormous amount to its development. When they started in 1996 the national literacy project and the national numeracy project were built on the experience of teachers. Science could be built on the experience of teachers. It would not take much. It is just a reconceptualisation of what an initiative is.

**Q198 Chairman:** Thank you very much. What you have told us is going to be very important to us. Thank you for spending the time. If anything occurs to you that you think we need to know after you have left here, please write to us and we will include it. Thank you very much indeed.

*Mr Bangs:* We will e-mail the evidence for the review body.

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#### Supplementary memorandum by Ms Elspeth Farrar, Director, Careers Advisory Service

As a response to the comment quoted by the Institute of Physics about the lack of careers advisers with a physical science background. The Committee might like to know that of the 132 higher education careers services at least 30 per cent have indicated that they have in their employ one or more careers advisers with a



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physical science or engineering background. It is reasonable to assume that qualified careers advisers working in schools (not careers teachers or connexions personal advisers) would have a similar profile. However, I would stress that providing careers guidance is in no way impaired by the lack of the same degree discipline to the students being advised. Guidance skills are essentially generic in their nature as no service, whether school or university based, can afford the luxury of having advisers to cover all discipline areas and so advisers are skilled in assisting clients from all backgrounds. Information provision is obviously degree specific but part of a careers adviser's training in understanding how to research a wide variety of specific careers options and also enabling and signposting students in conducting their own career research.

Secondly, I would also like the Committee to be aware of the issue around gaining Chartered status for engineering students. In order to gain Chartered Engineering status, students would be required to progress on to a suitable job with a recognised company and complete the CPD process, which on an average takes up to five years. Any student who may wish to keep an engineering career as a possible option would find the requirements for chartered status an effective block on considering teaching as a career, at least for the five or so years after graduation.

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### **Memorandum by the Association for Science Education**

#### SUMMARY OF SUBMISSION

1. The Association for Science Education<sup>1</sup> (ASE) welcomes the opportunity to make this submission on *Science Teaching in Schools* and has consulted widely with its members who are drawn from all phases and areas of science education in order to bring together a range of evidence from a variety of perspectives.
2. Although the enquiry intends to examine specifically the teaching of physics, biology, chemistry and mathematics from Key Stage 3 to A-level in state schools, ASE would wish to emphasise the importance of high quality Primary Science that forms the foundation on which work at KS3 and beyond is built.
3. ASE would also wish to draw The Committee's attention to the commentary<sup>2</sup> *Science education in schools: issues, evidence and proposals*, prepared jointly by the Teaching and Learning Research Programme of ESRC and ASE, a copy of which forms part of our submission.
4. The key messages are summarised below.
5. Availability and quality of information and evidence on science teaching.
  - ASE is concerned that the quality of evidence on which decisions relating to science teaching are based is less than adequate and would urge the Committee to consider ways in which this situation can be improved in order to better inform the evaluation of initiatives and policies.
6. Attracting and retaining top class science teachers, technicians and support staff
7. Science Teachers
  - In essence, school science's most valuable resource is not its equipment or its laboratories but a cadre of well-qualified, enthusiastic teachers who are justly remunerated for their skills.<sup>3</sup>
  - A more targeted strategy is required in order to engage teachers with their own subject specialisms, especially in the shortage areas of physics and chemistry.
  - Recognition and reward for science teachers who demonstrate high quality professional expertise is essential for retention.
8. Science Technicians and teaching assistants
  - Skilled and experienced science specialist technicians and teaching assistants, working alongside teachers, contribute to effective teaching of science.
  - The role of science technician should be more explicitly recognised in the school workforce structures.
  - Funding to support technicians for training and registration for qualifications should be made more accessible.

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<sup>1</sup> Appendix 1 provides a summary of the aims of The Association for Science Education.

<sup>2</sup> *Science education in schools: issues, evidence and proposals*, TLRP and ASE (2006).

<sup>3</sup> *Pupils' and Parents' views of the school science curriculum*. Osborne, J and Collins, S (2000) London: King's College London, School of Education.

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9. Enhancing the quality of science teaching

- Student views cannot be ignored.
- Teachers have aspirations to improve the quality of their own teaching but they have concerns and perceive barriers which inhibit them taking appropriate action.
- The time available for preparing good science teachers is short and greater attention need so to be given to ensuring that programmes for trainees and their subsequent induction year, as a newly qualified teacher (NQT), are integrated much more closely.
- All NQTs would benefit from a staged introduction to full-time teaching and a planned programme for their continued development.
- A blended approach to CPD is required which has the support and commitment of all parties—the Government, school management and individual teachers.

10. Impact of curriculum change and other initiatives

- “Teaching to the test” leads to a narrowing of not only teaching approaches and activities but also to the quality of knowledge and understanding gained by pupils and their engagement with the subject.
- To meet student needs we must build flexibility into the curriculum otherwise risk ending up with another “one-size fits all” model and many of the problems we face today will simply return at some point in the future.
- Practical work is central to teaching and learning in science but it must be well planned and resourced appropriately.
- The rate at which system wide change has been and is being introduced is becoming counter-productive and is leading to a reduction in the degree to which teachers feel they have ownership of what they teach.

11. Improving and extending the environment for teaching and learning in science

- The Building Schools for the Future Programme needs to engage more fully with the science education community in order to understand better the needs of science.
- Greater use to the outdoors in science teaching and learning should be encouraged but this requires greater support from government and others in order to emphasise its importance and to make it affordable.

12. Strengthening links and networks

- Transition issues that arise when students move from one to phase to another must be addressed and the lessons learnt from new transition initiatives must be brought together and acted upon by relevant parties.

13. Science Education is not perfect but ASE has substantial evidence that there is a much to be celebrated and that there are significant numbers of well-qualified teachers of science in both primary and secondary schools who are engaging students in science everyday.

14. Introduction.

The Association for Science Education<sup>4</sup> (ASE) welcomes the opportunity to make this submission on *Science Teaching in Schools* and has consulted widely with its members who are drawn from all phases and areas of science education in order to bring together a range of evidence from a variety of perspectives. In particular, in addition to the information from external sources, this submission has drawn on first hand contributions from members of ASE Council, our two Special Interest Groups (National Advisers and Inspectors Group for Science<sup>5</sup> (NAIGS) and, Association of Tutors in Science Education<sup>6</sup> (ATSE)) and the findings of a series of nationwide seminars held earlier this year under the heading of *Engaging teachers, Engaging pupils, Engaging Science*.<sup>7</sup>

15. Although the enquiry intends to examine specifically the teaching of physics, biology, chemistry and mathematics from Key Stage 3 to A-level in state schools, ASE would wish to emphasise the importance of high quality Primary Science that forms the foundation on which work at KS3 and beyond is built. Despite the fact that primary science is widely regarded as a major success, there are issues which still need to be

<sup>4</sup> Appendix 1 provides a summary of the aims of The Association for Science Education.

<sup>5</sup> Appendix 2 provides a summary of the aims of The National Advisers and Inspectors Group for Science.

<sup>6</sup> Appendix 3 provides a summary of the aims of The Association of Tutors in Science Education.

<sup>7</sup> Appendix 4 provides a discussion document prepared at an interim stage of the seminar series and highlights some of the findings. A full report with recommendations is currently being prepared.

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addressed. Indeed many of the challenges faced by Primary Science are very similar to those outlined below for KS3 and beyond. The Postnote<sup>8</sup> on primary science and more recently the *Primary Horizons report*<sup>9</sup> published by The Wellcome Trust set out the issues for Primary Science in more detail.

16. ASE would also wish to draw The Committee's attention to the commentary<sup>10</sup> *Science education in schools: issues, evidence and proposals*, prepared jointly by the Teaching and Learning Research Programme of ESRC and ASE, a copy of which forms part of our submission. In this document we draw attention to the following issues:

1. Availability and quality of information and evidence on science teaching.
2. Attracting and retaining top class science teachers, technicians and support staff.
3. Enhancing the quality of science teaching.
4. Impact of curriculum change and other initiatives.
5. Improving and extending the environment for teaching and learning in science.
6. Strengthening links and networks.

17. Availability and quality of information and evidence on science teaching.

18. Key message:

- ASE is concerned that the quality of evidence on which decisions relating to science teaching are based is less than adequate and would urge the Committee to consider ways in which this situation can be improved in order to better inform the evaluation of initiatives and policies.

19. ASE is very aware that the Committee will be provided with a substantial volume of evidence and will have access to significant amounts of statistical information referring to, among other things, the current situation of teacher supply and demand. However, despite the fact that there appears to be large volumes of information available our experience is that much of it is not readily accessible and not sophisticated enough to be able to address adequately questions that relate to the individual disciplines of science. Indeed it has been left to professional bodies (eg Royal Society of Chemistry and Institute of Physics) to fund research in order to gather key data in order to inform policy and practice. The recent study undertaken by NFER,<sup>11</sup> however, provides a starting point for further clarification about the existing population of science teachers but ASE is unaware of any plans to systematically monitor the situation over the coming years.

20. Furthermore, information relating to matters such as the quality of science teaching and laboratory provision has to date been collected by OfSTED through its inspection and reporting procedures. However, the recently introduced arrangements for shortened inspections have restricted the requirements for subject specific information during school inspections and significantly reduced the number of subject survey visits that can be made. This change in practice will therefore restrict the amount of evidence available on which to judge the provisions for, and quality of, science teaching.

21. In order to establish the impact of the actions that are being introduced to improve science teaching in schools it is important that there is good quality, relevant data available. ASE with NAIGS is attempting to address this in a small way by trying to establish a database<sup>12</sup> on science departments to build up information on some core metrics such as the number of teachers and their specialisms in a department, the amount of money that is spent on equipment and consumables and the use of laboratories. The intention, over time, is to create a national databank that can be used to monitor developments and provide comparative information year on year and region by region.

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<sup>8</sup> *Postnote: Primary Science Parliamentary Office of Science and Technology* (September 2003).

<sup>9</sup> *Primary Horizons: Starting Out in Science* The Wellcome Trust (2005).

<sup>10</sup> *Science education in schools: issues, evidence and proposals*, TLRP and ASE (2006).

<sup>11</sup> *Mathematics and Science in Secondary Schools: The Deployment of Teachers and Support Staff to Deliver the Curriculum* DfES/NFER (2006).

<sup>12</sup> *Science in schools: a national picture* Singleton L (2006) Education in Science April 2006.

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22. Attracting and retaining top class science teachers, technicians and support staff.

### Science Teachers

#### Key messages:

- In essence, school science's most valuable resource is not its equipment or its laboratories but a cadre of well-qualified, enthusiastic teachers who are justly remunerated for their skills.<sup>13</sup>
- A more targeted strategy is required in order to engage teachers with their own subject specialisms, especially in the shortage areas of physics and chemistry.
- Recognition and reward for science teachers who demonstrate high quality professional expertise is essential for retention.

23. Although there are indications that recruitment on to training programmes for science overall is showing an improvement, the overall size of the population is still less than ideal. Recruitment incentives such as “golden hellos” are helpful in attracting trainees but the evidence as to the long term effect is not yet clear. Employment-based routes, notably the Graduate Teacher Programme, have made a significant contribution to recruitment but the incentives, especially for someone who is changing careers, are not generous.

24. Moreover, it is well documented<sup>14</sup> that there is an imbalance between specialist subject teachers for sciences. 44 per cent of all science teachers have biology as their specialism compared with 25 per cent for chemistry and 19 per cent for physics. Furthermore 11–16 schools in poorer areas and lower ability pupils tend to have less subject specialists. 26 per cent of 11–16 schools do not have any physics specialists. With a decline in trainee teachers of physics and chemistry in recent years, an ageing science teacher population, especially with physics and chemistry specialisms,<sup>15</sup> rising salaries for new science graduates and 40 per cent of science teachers leaving in first five years,<sup>16</sup> it is unlikely that the government targets for recruitment, retraining and retention as outlined in *Science and Innovation Investment Framework 2004-2014: Next Steps*<sup>17</sup> will be met.

25. Efforts are being made to address this imbalance through booster and enhancement courses for science trainee teachers in areas outside their specialism such as the IOP Physics Enhancement Programme and other initiatives such as the IOP Supporting Physics Teaching Project. Such initiatives are most successful when they combine elements of specific subject knowledge with effective specific subject teaching. Opportunities to share good practice with colleagues are helpful in developing such knowledge and skills. In order to meet the existing demands further efforts to retrain individuals needs to be stepped up and ASE welcomes the Government commitment to develop and pilot a CPD programme leading to an accredited diploma to give existing science teachers without a physics or chemistry specialism the deep subject knowledge and pedagogy they need to teach these subjects effectively. However these are mainly short term solutions and in the longer term, a more targeted strategy is required in order to engage teachers with their own subject specialisms, especially in the shortage areas of physics and chemistry.

26. Whilst the focus of this imbalance of specialisms is on shortages in physics and chemistry, it must be noted that the situation for biology is not unproblematic. Given the wide range of biological science degrees, it is perfectly possible for biology teachers to have restricted knowledge of particular aspects of biology.

27. The imbalance of recruitment to Initial Training Programmes has a knock-on effect in schools. This is compounded by the regional variations with urban areas showing the major difficulties for recruitment especially at Head of Department (Subject Leader) level.

28. Retention, however, is perhaps a bigger issue than recruitment. Although there is evidence that 60 per cent of those who enter the profession are still teaching after five years, the loss of talent is considerable. Reasons for leaving are complex and may not be specific or unique to science teaching. For example, 58 per cent of teachers cite workload as a major reason for leaving the profession.<sup>18</sup> Incentives and entitlement to CPD for developing and updating subject knowledge as well as pedagogy would be well received and contribute to retention. ASE therefore welcomes the commitment of Government to remit the STRB to advise on improving the use of current pay incentives and flexibilities to improve recruitment, retention and quality of science and

<sup>13</sup> *Pupils' and Parents' views of the school science curriculum*. Osborne, J and Collins, S (2000) London: King's College London, School of Education.

<sup>14</sup> *Mathematics and Science in Secondary Schools: The Deployment of Teachers and Support Staff to Deliver the Curriculum* DfES/NFER (2006).

<sup>15</sup> *Teacher Turnover, Wastage and Destinations* Smithers, A and Robinson P (2004), DfES London.

<sup>16</sup> Howson, Recent Intelligence EDS, unpublished 2006.

<sup>17</sup> *Science and Innovation Investment Framework 2004–2014: Next Steps* HM Treasury/DTI/DfES/ Department of Health (2006).

<sup>18</sup> *Chemistry Teachers: A Report for the Royal Society of Chemistry* Smithers, A and Robinson, P (2001).

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maths teachers. However it should be noted that implementation of differential schemes could be divisive within the overall teaching profession.

29. Recognition and reward for science teachers who demonstrate high quality professional expertise is essential for retention. As a contribution to this ASE in partnership with the Science Council has launched the Chartered Science Teacher<sup>19</sup> (CSciTeach) designation, which, we would argue, deserves widespread support and backing from Government and the science community.

30. Science Technicians and teaching assistants

Key messages:

- Skilled and experienced science specialist technicians and teaching assistants, working alongside teachers, contribute to effective teaching of science.
- The role of science technician should be more explicitly recognised in the school workforce structures.
- Funding to support technicians for training and registration for qualifications should be made more accessible.

31. The importance of good science technicians supporting school science departments to provide exciting, relevant, practically-based courses in science cannot be underestimated. A survey<sup>20</sup> undertaken by the ASE and The Royal Society provided a unique database of information on the roles, responsibilities, working conditions and opinions of laboratory technicians working in secondary schools and colleges. The recommendations<sup>21</sup> set out in the follow-up report mapped out ways forward for improving the status and recognition of science technicians working in schools and colleges.

32. Progress has been made against the recommendations but there are still several fundamental issues<sup>22</sup> that need to be addressed relating to:

- the implementation of an improved career structure;
- opportunities for technicians to gain recognised qualifications which ASE has taken forward in partnership with the Design and Technology Association through funding from Gatsby Charitable Trust;
- funding of technicians to attend courses and register for qualifications.

33. Although it is early days the introduction of Higher Level Teaching Assistants specialising in science has some obvious potential benefits. Proposals<sup>23</sup> to deploy some 7,000 specialist HLTAs for maths and science offer a good opportunity to provide additional support for teaching and learning in science. However there is the strong possibility of tension due to lack of clarity in distinguishing the roles of technicians and HLTAs and their conditions of service.

34. Enhancing the quality of science teaching

Key messages:

- Student views cannot be ignored.
- Teachers have aspirations to improve the quality of their own teaching but they have concerns and perceive barriers which inhibit them taking appropriate action.
- The time available for preparing good science teachers is short and greater attention needs to be given to ensuring that programmes for trainees and their subsequent induction year, as a newly qualified teacher (NQT), are integrated much more closely.
- All NQTs would benefit from a staged introduction to full-time teaching and a planned programme for their continued development.
- A blended approach to CPD is required which has the support and commitment of all parties—the Government, school management and individual teachers.

<sup>19</sup> *Recognising professional expertise: Chartered Science Teacher* Bell D and Lawrence J (2006) Education in Science April 2006.

<sup>20</sup> *Survey of science technicians in schools and colleges* ASE and Royal Society (2001).

<sup>21</sup> *Supporting success: science technicians in schools and colleges* ASE and Royal Society (2002).

<sup>22</sup> Appendix 5 provides a summary of issues on the provision of laboratory technicians and teaching assistants.

<sup>23</sup> *Developing people to support learning: a skills strategy for the wider school workforce*. School Workforce Development Board, TDA (2006) Available at <http://www.tda.gov.uk/support/swdb/swdb2006to09.aspx>

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35. Teaching and learning are complex processes and science teachers are exposed to a wide range of often conflicting demands. The building up of high quality professional expertise through both pre-service training and ongoing professional development is therefore crucial to high quality science teaching. The quality of teaching and learning which is derived is at the heart of any school improvement and depends not only on the relationships that develop between the teacher and student and between students but also on the interactions between curriculum, assessment and pedagogy.

#### 36. Students' views

Students are the recipients of science teaching in schools and as such their views have a place. However these are rarely taken into account yet they can provide excellent feedback both at a school and national level. For example, as a student lead review<sup>24</sup> of the science curriculum concluded “there is great potential but school science fails to convey the extent to which science is related to everyday life and affects all of us. Space needs to be made to allow controversial issues to be included and to allow topics to be studied in more depth.”

#### 37. Teachers' views

OfSTED has reported improvements in the overall quality of science teaching in recent years but there remain many concerns raised by teachers and their perceptions of their role. Against this background ASE, working with other partners notably the National Network of Science Learning Centres under took a seminar series<sup>25</sup> to explore teachers' views on their concerns and aspirations to improve the quality of their teaching and the learning experiences and achievements of their students.

38. The main concerns and barriers expressed by teachers clustered around seven issues: lack of time, narrowness of teaching repertoire, assessment regimes, subject knowledge, lack of confidence and ownership, professional development and school management. As the discussion paper at Appendix 4 demonstrates they all are seen as major constraints to quality teacher and learning.

39. More positively teachers have aspirations in relation to their own teaching and what they feel they need in order to improve their own expertise, support their colleagues and enhance the learning of their students. Their aspirations fall into four areas—pedagogy and resources, assessment, leadership, continuing professional development—all of which need to be addressed. Appendix 4 again illustrates teachers' views. The discussion paper also outlines how, for one group of teachers, the barriers they identified impacted and restricted them in meeting their aspirations. Analysis of the questions raised for subsequent discussions is ongoing and it is intended to publish a report later in the year.

#### 40. Professional Development: Initial Teacher Education Programmes (ITE)

Professional development for teachers commences with their pre-service training and should continue throughout their career. It is important therefore that the process is seen as a continuum and not as separate elements. The development by the TDA of standards for classroom teachers, which are currently out for statutory consultation, may contribute to supporting a more holistic view of teachers' professional development. However, if used inappropriately such standards could place yet another burden on individual teachers.

41. Current ITE provision has contributed to improvements in the quality of newly qualified teachers entering the profession. However such programmes are not without their shortcomings which include:

- the time to develop in-depth subject knowledge, especially across all the sciences, is inadequate;
- the balance of time between “school-based” and “college-based” work which needs to be reviewed to allow more quality time for reflection and trying out activities, notably practical experiments with support.

42. In short the time available for preparing good science teachers is brief and greater attention needs to be given to ensuring that programmes for trainees and their subsequent induction year, as a newly qualified teacher (NQT), are integrated much more closely.

#### 43. Professional Development: Newly qualified teachers and induction

NQTs entering the profession take with them their career entry profile which sets out strengths and areas for development. In theory each individual has an entitlement to support during that first year but, in practice, the feedback we have received suggests that many do not receive the levels of support required. All NQTs would benefit from a staged introduction to full-time teaching and a planned programme for their continued

<sup>24</sup> *Student Review of the curriculum: major findings*. Planet Science (2003).

<sup>25</sup> Appendix 4 *Engaging teacher, Engaging pupil, Engaging Science: a discussion paper*. Was prepared at an interim stage of the seminar series and highlights some of the findings. A full report with recommendations is currently being prepared.

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development. In Scotland, for example, new teachers are timetabled for no more than 70 per cent of their time and schools are provided with additional funding to support this.

44. Meeting individual needs of NQTs is a challenge for schools as programmes need, by definition, to be personalised through mentoring (in the region of four hours per week) feedback from lesson observations (GTP students often need additional support on pedagogy) and opportunities to meet with other NQTs and colleagues. All this takes time, which too often is not made available potentially contributing to higher than necessary “dropout” rates.

45. Professional Development: continuing professional development

The importance of continuing professional development (CPD) is now widely accepted but, despite a wide range of CPD opportunities that are available through LEAs, ASE, CLEAPSS, NNSLC and others, the uptake, especially in subject-specific CPD, has declined in recent years. Indeed the recent report<sup>26</sup> published by The Wellcome Trust indicated that 50 per cent of science teachers had not had any subject specific CPD in the last five years.

46. From our experience of running the ASE Certificate of Professional Development, CPD needs to be tailored to individual needs in the context of their own school situation (hence making a contribution to the overall objectives of their department and school), develop classroom management, leadership and career development as well as their subject knowledge and pedagogy. These features are also reflected in more detail in the professional development framework for science teachers that has been developed through the Astra Zeneca Science Teaching Trust.<sup>27</sup>

47. CPD requires a balance of elements including attendance on courses and conferences, time working with colleagues in school and personal reading and reflection. Such a blended approach requires commitment from a range of parties, the government, school management teams and individual teachers. CPD should be an entitlement with appropriate incentives but it also brings with it responsibilities for all those involved. Working towards, achieving and maintaining the Chartered Science Teacher (CSciTeach) designation is one way for individual teachers to demonstrate their commitment and acceptance of their responsibility for their CPD. This in combination with wider developments could make a significant contribution to the status and quality of science teaching by providing both recognition and, where appropriate, rewards.

48. Impact of curriculum change and other initiatives

Key messages:

- “Teaching to the test” leads to a narrowing of not only teaching approaches and activities but also to the quality of knowledge and understanding gained by pupils and their engagement with the subject.
- To meet student needs we must build flexibility into the curriculum otherwise risk ending up with another “one-size fits all” model and many of the problems we face today will simply return at some point in the future.
- Practical work is central to teaching and learning in science but it must be well planned and resourced appropriately.
- The rate at which system wide change has been and is being introduced is becoming counter-productive and is leading to a reduction in the degree to which teachers feel they have ownership of what they teach.

49. The curriculum and assessment requirements have a significant impact on the quality of science teaching and learning that takes place. More importantly the way in which they are implemented has more profound effects on the experiences and learning of students. Put simply “teaching to the test” leads to a narrowing of not only teaching approaches and activities but also to the quality of knowledge and understanding gained by pupils and their engagement with the subject.

50. Meeting student needs

Meeting student needs often has to come back to the idea that the curriculum must be seen by them as relevant in some way to their everyday life. For some students relevant means the work should be “applied” eg the need to understand the chemistry of polymers as a basis for making new materials. For others it is the need for some “personal link” such as knowing someone with a heart defect as a stimulus to find out more about the structure and function of the heart. Discussion of “ethical issues”, hearing about a recent scientific discovery or of a person in science are other things that can make science relevant. For some students some things are relevant

<sup>26</sup> Believers, seekers and skeptics: What teachers think about continuing professional development Wellcome Trust (2006).

<sup>27</sup> Astra Zeneca Science Education Forum: Professional Development Planner (2006) available at <http://sef.sciencelearningcentres.org.uk/>

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simply because they are found to be fascinating. The key message here is that if we are to meet student needs we must build flexibility in to the curriculum otherwise risk ending up with another “one-size fits all” model and many of the problems we face today will simply return at some point in the future.

51. ASE promotes science for all students and therefore provision must be made for students with special educational needs in order to support those with learning difficulties, physical disabilities, behavioural problems as well as those who are gifted and talented.

#### 52. Practical work in science

One of the key elements of science teaching is the central role of practical work which offers opportunities for the development of a wide range of both subject specific and more general skills that are highly valued and contribute to students’ learning and personal development. However in recent years there is evidence that the amount and quality of practical work has declined for a variety of reasons which include:

- the demands of the assessment procedures for GCSE which have lead to teachers becoming reliant on well-known, easily managed practicals in which students can score highly thus reducing the variety and creativity that encourages student engagement;
- the lack of confidence of teachers to undertake practical activities (including fieldwork) because of their own restricted experience, lack of time to try out experiments in advance and the perceptions that things are banned<sup>28</sup> on health and safety grounds;
- increases in class-size which make management of practical work more difficult;
- the quality of laboratory provision which is considered in Appendix 5 below.

53. Ironically these and other factors have led to circumstances in which practical work has become routine and uninspiring so that, rather than engaging students with the excitement of science, such experiences contribute to students considering science as “boring”.

#### 54. Curriculum change

Curriculum change is an endless and ongoing task. This is appropriate as a key ingredient in striving to provide learning experiences which students see as relevant and appropriate to themselves. However the rate at which system wide change has been, and is being introduced, is becoming counter-productive. Whilst there is some merit in many of the changes rarely has there been time to learn from the results of the changes. Currently, for example, the introduction of the new GCSEs has been brought about before all the findings of the pilot are known. Specifications for AS/A2 are now being revised for 2008 before the GCSE changes have been implemented. Anticipating requirements is important but the pressures on teachers mitigate against them becoming fully involved in the consultations and engaging with the issues.

55. The plethora of initiatives which face teachers and others adds further confusion resulting in “overload” and potential inertia as schools and teachers attempt to meet the many demands placed on them. One of the overwhelming effects of this and the increased central control over the curriculum has lead to a reduction in the degree to which teachers feel they have ownership of what they teach.<sup>29</sup>

56. The style and nature of assessment has a significant effect on what and how things are taught. As indicated above with practical work this burden and the requirements of examinations have further restricted the scope of topics taught.

57. One of the effects of the changes to the “formal” curriculum is the change in attitude towards “informal” activities. This seems to be manifest in a variety of ways according to circumstances. In many schools it means nothing if it is done outside the statutory curriculum, fewer activities are undertaken outside normal school hours and perhaps, most worrying, the extra-curricula activities are regarded as separate from the topics covered in the “formal” curriculum. The overall experience of science available to students involves both elements. It is important therefore to find ways to increase the availability of enhancement schemes to support teachers and their students. The outcomes of the STEM Mapping review,<sup>30</sup> the development of Regional School Science Centres<sup>31</sup> and increased co-ordination of existing schemes (eg BA CREST Awards, Royal Society Partnership Grants, Researchers in Residence programme, Nuffield Bursaries and the BEST programme) should help to increase the availability and benefits of science enhancement schemes.

<sup>28</sup> *Surely that's banned?* A report for the Royal Society of Chemistry on chemicals and procedures thought to be banned from use in schools (2005).

<sup>29</sup> Appendix 4 *Engaging teacher, Engaging pupil, Engaging Science: a discussion paper*. Was prepared at an interim stage of the seminar series and highlights some of the findings. A full report with recommendations is currently being prepared.

<sup>30</sup> Review currently being undertaken by DfES under the direction of Sir Alan Wilson.

<sup>31</sup> Originally referred to as Regional Hubs for School Science following a short study directed by Sir Gareth Roberts. Pilots are being conducted lead by SETNET in partnership with Science Learning Centres.



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58. Improving and extending the environment for teaching and learning in science

Key messages:

- The Building Schools for the Future Programme needs to engage more fully with the science education community in order to understand better the needs of science.
- Greater use of the outdoors in science teaching and learning should be encouraged but this requires greater support from government and others in order to emphasise its importance and to make it affordable.

59. There is no doubt that the quality of the environment for teaching and learning in science has a significant impact on the way in which students perceive science and steps must be taken to improve the situation more rapidly than is currently being done.

60. Science Laboratories

Many science lessons take place in laboratories which are considered unsafe, unsatisfactory or, at best, uninspiring, with inadequate spending and resources being available.<sup>32</sup> Preparation rooms are similarly inadequate with 40 per cent not being upgraded when the laboratories they served were improved. Indeed 16 per cent were actually made worse.<sup>33</sup> In addition many laboratories are too small for the size of groups for which they are used. This was recognised by DfES with a revision of the guidelines<sup>34</sup> to a recommended size to 90 sq metres for a maximum of 30 Key Stage 3 pupils. Although schemes and some funding<sup>35</sup> have been announced to improve the facilities for teaching science, the timescale is slow and, anecdotal evidence suggests that the results do not always meet the actual teaching and learning requirements.

61. Designing, refurbishing and building laboratories is a specialist and complex process which involves several parties getting together to agree the requirements.<sup>36</sup> Unfortunately the feedback we have obtained indicates that this is not true in many cases resulting in new laboratories that are not fit for purpose and in a small number of cases not workable. More effective and creative designs of laboratories are required that meet not only the practical requirements (including health and safety) for carrying out scientific experiments using up to date equipment and ICT (eg dataloggers) but also provide scope for other activities that contribute to overall learning. Some initiatives<sup>37</sup> are available but not widely known or understood. The Building Schools for the Future Programme needs to engage more fully with the science education community in order to understand better the needs of science.

62. Science technicians

The importance of fully qualified and supported technicians has been addressed in Appendix 2. It is noted here because it is often part of the role of the technician to ensure that the working environment is fully maintained and functional. The quality of that environment is therefore very dependent on the technicians.

63. Use of the outdoors

Traditionally biology and geology are the major sciences in which part of the teaching and learning takes place outdoors as fieldwork. However there are major opportunities for engaging with a much wider range of science topics outside the laboratory. Unfortunately, as the awareness of these wider opportunities has increased the use of the outdoors appears to have declined.

64. Elsewhere<sup>38</sup> arguments for the value of outdoor science and the potential for activities have been discussed at some length and are not reiterated here. However it is obvious that there is enormous untapped potential for enhancing teaching and learning in science. The advent of the Outdoor Manifesto, the continuing activities of the Real World Learning Campaign<sup>39</sup> and the drive to address issues of sustainable development in science education all point to the need to encourage greater use to the outdoors in science teaching and learning. This however requires greater support from government and others in order to emphasise its importance and to make it affordable.

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<sup>32</sup> *Laboratories, Resources and Budgets: A report for the Royal Society of Chemistry on Provision for Science in Secondary Schools* (2004).

<sup>33</sup> As above.

<sup>34</sup> Building Bulletin (BB80) revised 2004 available at <http://www.ase.org.uk/ldtl/docs/BB80.pdf>

<sup>35</sup> This includes £200 million announced by the DTI in the run up to the election but does not seem to have been allocated.

<sup>36</sup> See for example *Laboratory Design: are you involved?* Piggott A (2006) Education in Science February 2006.

<sup>37</sup> For example: Laboratory Design for Teaching and Learning website available at [www.ase.org.uk/ldtl](http://www.ase.org.uk/ldtl).

<sup>38</sup> See for example—*Outdoor Science*, School Science Review 87(320) March 2006.

<sup>39</sup> *Out-of-Classroom Learning; Practical information and guidance for schools and teachers* Real World Learning Partnership (2006).

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## 65. Strengthening links and networks

### Key messages:

- Transition issues that arise when students move from one to phase to another must be addressed and the lessons learnt from new transition initiatives must be brought together and acted upon by relevant parties.

66. Striving to improve science teaching and learning in schools, quite rightly, involves a very large number of stakeholders. Unfortunately this leads to tensions both in terms of the outcomes and the ways in which science education should be approached. Whilst ASE broadly supports the proposals in the Next Steps document<sup>40</sup> and will play its part in working towards the objectives, it must be remembered that there are wider issues involved. An overemphasis on such precise targets could lead to major failures elsewhere and to some students being disadvantaged.

67. The principles underpinning the KS4 programme of study on which the new GCSE's are based should not be lost. The emphasis on "how science works" and the importance of meeting the needs of students who will not go on to study science post-16 as well as those who will, resulted from a very broadly based consensus across both the science and science education communities. It is imperative that this is not lost in a drive for short-term gains. It is important therefore that links and dialogue between the different stakeholders are maintained and strengthened.

## 68. Networks

Currently there are many, often overlapping, networks involved in science education to a greater or lesser extent and steps need to be taken to enhance the effectiveness of these. In attempting to achieve this several issues must be addressed if the synergies are to be maximised. For example:

- greater dialogue is needed between parties;
- roles and purposes must be more clearly defined and communicated; and
- genuine partnerships must be formed with all parties (especially students) sharing in the benefits.

69. The outcomes of the STEM Mapping Review could help in this, as could the initiatives<sup>41</sup> currently being undertaken under to auspices of The Royal Academy of Engineering and the Royal Society. To be successful however other stakeholders must demonstrate their commitment.

## 70. Transition

A key element in the quality of science education must be the way in which the experiences available to students at different stages in their life link together. In terms of formal education this means the continuity and progression that develops between primary and secondary school, pre and post 16, school/college and University as well as, school/college/university and employment. In other words the transition issues that arise when students move from one to phase to another must be addressed.

71. Over recent years transition between primary and secondary phases has been improved but there is still work to be done. Currently there is some interest in transition between school and university specifically in science. The big danger is that much is taking place in isolation partly because as a result of funding arrangements<sup>42</sup> and there have been few attempts<sup>43</sup> to genuinely look at the total picture including curriculum needs across all age ranges. It is early days but it is important that the lessons learnt from transition initiatives must be brought together and acted upon.

## 72. Conclusion

Science Education is not perfect but ASE has substantial evidence that there is a much to be celebrated and that there are significant numbers of well-qualified teachers of science in both primary and secondary schools who are engaging students in science everyday. The challenge facing us all is ensure that the high quality teaching that exists is available to all pupils.

73. ASE, in accordance with it aims, is more than willing to continue to play its part in this endeavour and would be very pleased to discuss this submission, and any other issues, with The Committee.

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<sup>40</sup> *Science and Innovation Investment Framework 2004–2014: Next Steps* HM Treasury/DTI/DfES/ Department of Health (2006).

<sup>41</sup> RAEng and RS are leading separate parallel groups to develop ways of improving co-ordination of support for science.

<sup>42</sup> Funding for a number of pilot projects has been made available through HEFCE.

<sup>43</sup> *Enthusiasing the next generation: A report on the bioscience curriculum* by a working group established by the Biosciences Federation (2005).

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## APPENDIX ONE

### THE ASSOCIATION FOR SCIENCE EDUCATION

74. The Association for Science Education is the largest subject association in the UK, with approximately 18,000 members including teachers, technicians and others involved in science education. The Association plays a significant role in promoting excellence in teaching and learning science in schools and colleges. Working closely with the science professional bodies, industry and business, ASE provides a UK-wide network bringing together individuals and organisations to share good ideas, tackle challenges in science teaching, develop resources and foster high quality continuing professional development.

75. The objects and purposes of ASE are clearly stated in its Charter of Incorporation as the promoting of education by the following means.

- Improving the teaching of science;
- Providing an authoritative medium through which opinions of teachers of science may be expressed on educational matters; and
- Affording a means of communication among all persons and bodies of persons concerned with the teaching of science in particular and education in general.

76. In a more modern context,

The Association for Science Education aims to promote excellence in science teaching and learning by:

- (a) Encouraging participation in science education and increasing both new membership and the retention of existing members.
- (b) Enhancing professionalism for teachers, technicians and others through provision of high quality continuing professional development and promotion of chartered status.
- (c) Working in partnership with other organisations, thus maintaining and strengthening its position in influencing policy and its reputation for delivering cutting edge initiatives for its members and, through them, to the wider science education community.

77. Further details of the ASE and its regional, national and international activities can be found on its website ([www.ase.org.uk](http://www.ase.org.uk)).

## APPENDIX TWO

### THE ASSOCIATION OF TUTORS IN SCIENCE EDUCATION (ATSE)

78. This Special Interest Group of The Association for Science Education exists to:

- further the aims of The Association for Science Education;
- support the work of Science Tutors, mentors and others working in initial teacher education throughout the UK;
- facilitate the exchange of ideas about science education, and alert national agencies to issues of concern to the membership.

## APPENDIX THREE

### NATIONAL ADVISERS AND INSPECTORS GROUP FOR SCIENCE (NAIGS)

79. This Special Interest Group of The Association for Science Education exists to:

- further the aims of The Association for Science Education;
- support the work of Science advisers, inspectors and others working in a science advisory or support capacity throughout the UK;
- facilitate the exchange of ideas about science education, and alert national agencies to issues of concern to the membership.

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## APPENDIX FOUR

### THE ASSOCIATION FOR SCIENCE EDUCATION NATIONAL NETWORK OF SCIENCE LEARNING CENTRES Engaging Teachers . . . Engaging Pupils . . . Engaging Science

Teachers' views on teaching science in ways which will get pupils excited about the subject

#### DISCUSSION PAPER

##### 80. INTRODUCTION

If you were to walk into a science lesson in any school you may sense a buzz of excitement, observe pupils engaged in their work with enthusiastic, effective and engaged teachers delivering an engaging science curriculum. Alternatively you may experience the opposite—disaffected pupils, tired and dispirited teachers and an utterly tedious science curriculum—or something between these two extremes. You may well ask, “Why this disparity?” and “What can be done to ensure that all pupils (and teachers) are engaged in vibrant and engaging science lessons?”

81. In his Presidential Address to the ASE in January 2005, Sir Mike Tomlinson emphasised the importance of the role of teachers in developing the curriculum they teach and in making science exciting for their pupils. This idea was echoed by The Nuffield Review of 14–19 Education and Training in its second annual report when it argued that:

*“The curriculum should be seen as a creative act within schools, not something handed on. Hence the teacher should be a curriculum developer, not a transmitter, translating the national framework into planning in classrooms and at school. This creative aspect of teaching is undermined by the relentless pursuit of targets.”* (Executive Summary p 2).

82. Despite the pressures, the majority of science teachers want to interest their students in science and there still exists the enthusiasm and determination to improve the situation. The recent revision of the KS4 programme of study and the review of KS3 curriculum in England provide opportunities for revitalising curriculum development at the level of the school and laboratory. Developments elsewhere in the UK offer similar opportunities, as do calls for more creativity in primary schools. These opportunities, however, may be lost if teachers in both primary and secondary schools are unable to take advantage of such changes due to the barriers, perceived or actual, that currently exist.

##### 83. Aims

This discussion paper, which arises out of a 24 hour seminar held on 17–18 November 2005 at the National Science Learning Centre in York, aims to take the initial debate forward and provide the basis for further discussions throughout the country in order to determine the views of teachers as to how they, as teachers, can work to improve pupils' engagement with science and, crucially, what needs to be done to support them (nationally and locally) in their efforts.

##### 84. Concerns and barriers

Despite the wide variety of ways of expressing the complex mix of factors that are involved in teaching science there is a fundamental commonality, regardless of phase—primary, secondary or tertiary—in the concerns expressed. In addition to the particular issues listed below it is clear that, for whatever reason, there are some very strong perceptions that are held by teachers regarding what is statutory and what is advisory. Three particular “myths” are referred to frequently. The first is the belief that the QCA schemes of work at KS1, KS2 and KS3 are compulsory. The second is the misconception that many experiments are “banned”. The third is the “requirement” for a “three-part lesson”.

85. The main concerns and barriers seem to cluster around seven issues: lack of time, narrowness of teaching repertoire, assessment regime, subject knowledge, lack of confidence and ownership, professional development and school management. Each of the items in itself can be a major inhibitor to effective teaching and the impact of each one varies from situation to situation. However, as the quotes reported below clearly illustrate, these issues are seen to be significant concerns and barriers for teachers.

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86. Lack of time

“I never get time to think about my teaching.”

“Our medium term plans are so restrictive that there just isn’t time to experiment with new ideas.”

87. Narrowness of teaching repertoire

“We have to follow the QCA scheme of work in my school. It is really frustrating as I don’t think it is the best thing for some of my pupils, but the timing is so rigid that I can’t change it.”

“If you look at the technician order sheets in my department you’ll find some of my colleagues are doing hardly any practicals. Surely science is essentially a practical subject.”

88. Assessment regime

“After Christmas we do three or four mock SATs papers. No one seems to have the guts to just carry on teaching good interesting science.”

“Year 10 and 11 just seem to be on a treadmill of one module exam after another. That wouldn’t have inspired me to take science (and it certainly doesn’t inspire them)”

89. Subject Knowledge

“I feel less confident in my science knowledge than with history or geography for example. My science co-ordinator does her best to help but she isn’t very confident either.”

“I’m all for science teachers teaching science (and not just their specialist area) but one or two colleagues are expected to do this when they obviously don’t have the necessary background knowledge. I feel that they are really switching some pupils off.”

90. Lack of confidence and ownership

“There is so much pressure to get results that I just daren’t take risks.”

“Everyone is so paranoid about results that they seem afraid to innovate in case things go wrong.”

91. Professional development (CPD)

“It is always the same people who seem to go out on courses- those who are ‘in’ with senior management”

“Most of our CPD budget was used up on whole school CPD ie getting in visiting speakers.”

92. School management

“Senior management always seem to focus on ‘whole school’ issues. These don’t always match the needs of the science department.”

“I don’t think my head understands the needs of science at all, especially the practical nature of the subject.”

93. Aspirations

Teachers have aspirations in relation to their teaching and what they feel they need in order to improve their own teaching, support their colleagues and enhance the learning of their students. Aspirations broadly fall into four areas—pedagogy and resources, assessment, leadership, continuing professional development (CPD)—all of which need to be addressed if progress is to be made in removing the barriers and allaying concerns. Again the quotes illustrate the issues clearly.

94. Pedagogy and resources

I would like . . .

my job to be creative and have time to try out new ideas.

to be involved in developing teaching strategies.

to reflect on my teaching so that I can make improvements myself.

time to get used to new initiatives and to get them working in my classroom (before being presented with the next).

the resources I need to make my lessons exciting (ie a working fume cupboard, enough beakers etc . . .).

our medium term planning to be more flexible so that I had space to experiment with new ideas.

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95. Assessment

I would like . . .

- assessment to motivate my pupils and reward their success.
- assessment to encourage learning (and not be a full stop at the end of learning).
- to be able to continue teaching engaging science in Year 6, rather than feel pressured to do endless SATs preparation.

96. Leadership

I would like . . .

- to be empowered to do a good job.
- senior management to support my own professional development as well as the school's.

97. CPD

I would like . . .

- to have the right to a certain amount of CPD, without needing to ask for it all the time.
- CPD to support innovation and not just to encourage the following of a recommended method.
- science specific CPD.

98. Table 1, attached as an appendix, indicates some of the ways in which, based on the discussions at the York seminar, the concerns and barriers impact on the four areas outlined above.

Furthermore it is widely accepted that the quality of teaching and learning is at the heart of any improvement that might be achieved by a school and this in turn is dependent on what constitutes teachers' professional knowledge. This, however, is not always reflected in the way in which priorities are addressed in schools and nationally. One of the difficulties is the lack of a "common language" for discussing the issues and results in unnecessary tension and conflict which results from misunderstandings rather than fundamental differences in opinion.

99. Key questions to be addressed

This paper has attempted to provide an overview of the concerns, barriers and aspirations of teachers who are striving to present science to their students in a way which is engaging and meaningful. Three key questions arise, to which responses are invited.

100. Does the overview presented in this paper reflect the current situation?

- (a) Are there any major concerns or barriers that have been omitted?
- (b) Are the aspirations widely shared and are there others?

101. What needs to be done in order to meet the aspirations for engaging students of all ages more effectively?

This question should be considered at three levels:

- (c) What can/could be done by individual teachers (even if nothing else changed)?
- (d) What could be done in schools?
- (e) What needs to be done nationally by, for example, DfES, other government departments, QCA, Ofsted, Specialist Schools and Academies Trust, Science professional bodies and learned societies (including Royal Society, Institute of Physics, Royal Society of Chemistry, Institute of Biology,) Science Council?
- (f) In addition, what should ASE and the Network of Science Learning Centres be doing?

102. What are the key messages that need to be understood in order to initiate action?

This is also a multi-level question which might be characterised by asking what needs to be said to:

- (g) individual colleagues;
- (h) the subject leader in a school;
- (i) the senior management team;
- (j) the Secretary of State for Education.

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103. **APPENDIX: Table 1: IMPACT OF CONCERNS/BARRIERS ON ASPIRATIONS: the notes in the boxes aim to indicate ways in which the aspirations are NOT being met.** (The contents of this table are based on the discussions which took place during the 24-hour seminar held at the National Science Learning Centre, University of York on 17–18 November 2005.)

<i>Concern/Barrier</i>	<i>Aspirations</i>			
	<i>Pedagogy and resources: wish to be more creative</i>	<i>Assessment: should support learning better</i>	<i>Leadership: needs to empower more</i>	<i>CPD: appropriate to include subject focussed</i>
<i>Lack of time</i>	Too much to do in the time available	Takes time away from teaching	Focus on results increase pressure to teach to the test	Not enough time for reflection or subject focussed work
<i>Narrowness of teaching repertoire</i>	Pressures to use specific schemes of work	Focus on tests	As above	Little opportunity to find out about and try new ideas
<i>Assessment regime</i>	Results driven pressures restricts activities	Emphasis on summative diminishes impact of formative	Demands of league tables and targets increase central control	Geared to examination requirements
<i>Subject knowledge</i>	Lack of confidence in subject knowledge restricts range of activities	Need to get “right” terms—factual recall rather than understanding	Not always aware of needs at subject level	Need for sustained study
<i>Lack of confidence/ownership</i>	Risk averse—play safe in approach and activities	Focus on tests not subject understanding and enjoyment	Sense of needing permission to try something different	Feeling time cannot be taken to leave students (or they might miss something)
<i>Lack of Professional development</i>	Continue with standard activities. Few new ideas	Re-enforces test focus	Different priorities linked to school targets	Lack of reflection and development
<i>School management</i>	Lack of encouragement to try different things	Demands for further increases in grades and test scores	Pressures on SMT get pushed onto others	Tension between different priorities and availability of staff

#### APPENDIX FIVE

##### 104. Provision and use of Laboratory Technicians and Teaching Assistants

The importance and role of the technician in supporting a science department to deliver an exciting, relevant practically based course cannot be underestimated.

105. A survey<sup>1</sup> by the ASE and the Royal Society has yielded a unique database of information concerning the roles, responsibilities, working conditions and opinions of laboratory technicians working in secondary schools and colleges.

106. There are a number of issues that arise out of the recommendations<sup>2</sup> made in the follow up report which are described below.

107. *The level of technician support for science in schools is not adequate by any of the commonly used measures to determine the number of technicians required.*<sup>2, 3</sup> Without adequate numbers of science technicians the learning experiences of students will be impaired, raising levels of achievement will be much more difficult, and safety in school laboratories will be compromised. The recommendation is to recruit up to 4,000 additional science technicians.

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108. A clear job description for all technicians has been described and is available to all schools.<sup>3</sup> *The recommendation is that technicians have a clear job description linked to a national career structure, pay scale and continuing professional development.*

109. A career structure for technicians in schools based on four levels has been published<sup>4</sup>. This is supported by over 20 organisations. *There should be a nationally agreed career structure for science technicians working in schools.*

110. National Occupational Standards for laboratory technicians have been developed. The Laboratory and Associated Technical Activities (LATA) National Vocational Qualification (NVQ) provides a framework in which existing skills can formally recognised, it supports a career progression pathway and encourages technicians to develop their skills throughout their careers.

111. A national assessment centre (techcen<sup>5</sup>) for technicians has been established. This is a joint project with the D&T Association, to a “virtual centre” website. This is a major initiative, funded in the first instance by Gatsby, to develop online assessment methods. This will simplify the qualification process and enable technicians to take responsibility for their own professional development. The project should be supported.

112. Registered Technician (RTech) status is being explored with the Engineering Council. Technicians in schools have a vital role to play in the provision of high quality science education. *National support for Registration would support the development of a suitable career for technicians.* Registration would mean demonstrating competence to perform professional work to the necessary standards and a commitment to maintain that competence, work within professional codes and participate actively within the profession.

113. An induction programme for technicians has been described<sup>6</sup>. *There should be a nationally recognised induction programme for technicians.*

114. An induction programme for Teaching Assistants (TA) in secondary science has been described<sup>7</sup>. While this may adequately cover the first stage of induction, a more detailed programme covering science-specific aspects including health and safety training for teaching assistants has been produced by ASE<sup>8</sup> and should be used in schools.

115. The role of the Higher Level Teaching Assistant (HLTA) in science needs to be explored. There are plans<sup>9</sup> to deploy some 7,000 specialist maths and science HLTAs, enabling each school to have one. There should be detailed hands-on science including health and safety training if that HLTA is to contribute to practical activities in the laboratory.

116. Technicians as HLTA (Specialist & technical) Science is a practical subject, and good quality “hands-on” activities, which involve students undertaking experimentation and investigative work, add hugely to the experience of learning science. If students are to experience such work, a well trained technician service is essential. Existing science technicians might, with suitable additional training, wish to act as a specialist HLTA in the laboratory. It must be understood that if this is the case, extra technician help will be needed in the science department to compensate for lost time.

117. *The profession of science technician is not attracting young recruits.* The apprenticeship route is being explored, but the issues are largely about pay and conditions. Being a technician should be seen as an attractive and viable career.

118. Funding for Continuing Professional Development. While a recommendation for ring fenced funding for the CPD of science technicians was made in the original report, we are now recommending that technicians can access funds set aside for training TA’s or HLTA’s, for example. While ASE INSET Services reports on the popularity of technician courses vs. teacher courses, there is little funding, through for example, Learning Skills Council (LSC) to support the NVQ process.

#### 119. REFERENCES

1. *Survey of science technicians in schools and colleges* (ASE & Royal Society, 2001)
2. *Supporting success: science technicians in schools and colleges* (ASE and Royal Society, 2002).
3. *Technicians and their jobs* (CLEAPSS guide L228, 2002).
4. *A career structure for science technicians in schools and colleges.* leaflet (ASE, 2004)
5. [www.techcen.org](http://www.techcen.org)
6. *Induction and training for science technicians* (CLEAPSS guide L234, 2003).
7. *Induction training for teaching assistants in secondary science: science module* (DfES, 2004).



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8. *Health and safety training for teaching assistants working in science in secondary schools* (EiS, June 2004).
9. *Developing people to support learning: a skills strategy for the wider school workforce* (School Workforce Development Board, 2006).

### Memorandum by CLEAPSS

#### SCIENCE TEACHING IN SCHOOLS

1. We wish to offer views and evidence on the adequacy of professional support for science teachers, the role of practical in teaching science, the condition of school labs and the provision and use of lab technicians.
2. Our submission concentrates on secondary science. It supports the following ideas.
  - Although CPD is available to science teachers, pressures in-school mean that they are reluctant or unable to leave classes to take advantage of what is being offered.
  - Appropriate practical work enhances pupils' experience, understanding, skills and enjoyment of science. A lack of experience, expertise and training are some of the factors which have led to teachers making less use than before of practical work, both demonstrations and class practicals, in their lessons, to the detriment of the learning and enjoyment of science by both pupils and teachers.
  - Many science lessons take place in labs which are unsafe/unsatisfactory or uninspiring and 13 per cent of science lessons do not take place in a lab at all.
  - The provision of science technicians is generally inadequate but technicians themselves, despite low pay and status, are committed to their work.

#### THE ADEQUACY OF PROFESSIONAL SUPPORT FOR SCIENCE TEACHERS

3. CLEAPSS offers a range of professional development courses mainly in the context of science but also occasionally for Design and Technology. Our courses are for secondary teachers, science technicians, occasionally primary teachers of science and local authority science advisers/inspectors and health and safety advisers.
4. CLEAPSS is well known within the school science community for providing advice and guidance on matters to do with health and safety in science education. However, our brief is the promotion of interesting and effective practical work in school science and our health and safety advice is intended to help teachers and technicians prepare and undertake practical work with pupils with appropriate regard to hazards and risk. All of our CPD courses follow this approach and many of our courses include a substantial amount of practical activity, either demonstrations or undertaken by the participants.
5. We have found that the uptake of our courses by science teachers has fallen significantly whilst that for science technicians has risen. Figure 1 gives some details. In our discussions with teachers and technicians we are told that, increasingly, teachers are not willing, or not allowed, to attend courses during term time, for fear of jeopardising the education of pupils. In addition, it is clear that training offered, by others and very occasionally ourselves, out of term time, say on Saturdays or during school holidays, commonly fails to attract a sufficient number of participants to be viable. Sending a technician on a training course is cheaper than sending a teacher by virtue of not needing to pay supply teacher costs, but we do not know how significant this is to schools.

	<i>1995–2000</i>	<i>2000–05</i>
Total number of courses	978	881
Number of courses for heads of science or science teachers	224 (23%)	93 (10%)
Number of courses for secondary science technicians	598 (61%)	664 (75%)

Fig 1: Participants in CLEAPSS science courses over the past 10 years. Not included in the percentages are courses for D&T and those for officers and teachers which focus on H&S legislation including the implementation of regulations governing radioactive substances.

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6. Last year (2005–06) the number of courses run by CLEAPSS rose by around 20 per cent to 212. The number for technicians remained much as in the previous year whereas those for secondary teachers rose to 35; an increase of 15 courses or 75 per cent. The reasons for the increase are:

- local authorities combining short courses to provide teachers with the opportunity to select a half-day or full-day training as appropriate;
- Science Learning Centres making course available and promoting them;
- some recruitment of technicians onto courses designated mainly for teachers allowing an otherwise non-viable course to go ahead.

CLEAPSS has provided training in some rather spectacular chemistry demonstrations via Teachers' TV. One of these contributions (including the howling jelly baby experiment) is the most down-loaded programme on the Teachers' TV web site.

It would seem therefore that some science teachers are able to take advantage of CLEAPSS CPD given sufficient availability and flexibility of provision.

7. It is our experience that teachers new to the profession, and those who arrive as teachers from overseas, have much less experience and expertise in the sorts of practical work which was commonly done in UK schools 20 or 30 years ago. Teachers are being required to achieve better examination results and one response to this has been to focus more on "book learning" which is more easily managed and assessed. Although the role and value of practical work is widely appreciated by science teachers, there is insufficient opportunity for them to learn about, and practice, activities before lessons. Teachers' working days are invariably busy and there is a tendency towards lessons which follow the department scheme of work, itself reliant on what its authors know works and can be easily managed. Commercially-published schemes of work are similar in that authors tend to play safe by suggesting mainly well-known, easily-managed practical work. Overall, this has the obvious effect of reducing the variety of practical activities which will be undertaken in any one school. Another consequence has been some de-skilling of teachers making them less able to generate novel and interesting practical activities.

8. CLEAPSS is very keen to encourage greater teacher participation in the sort of CPD we offer in order to give teachers more direct experience of practical activities, particularly those which are popularly believed to be no longer allowed. Science technicians on our courses often remark on the value of the practical experiences we provide and how useful they would be to their teacher colleagues. We would agree.

#### THE ROLE OF THE PRACTICAL IN TEACHING SCIENCE

9. It is well recognised that practical work has been, and remains, one reason why pupils enjoy science and often rate it among their most enjoyable school subjects. Recently this level of "customer satisfaction" has fallen away, particularly during the latter secondary years, and probably as a consequence of a reduction in the amount of interesting practical work being undertaken. There have been questions about the value of practical work to pupils' learning of scientific information, but there is no doubt that pupils gain an appreciation of how science can be carried out by engaging with hands-on practical. In addition, if appropriately taught, they can develop their understanding that science is not as absolute in its findings as some would like to believe.

10. CLEAPSS offers a telephone helpline for members wanting quick information or advice. The majority of calls to the helpline are to do with some aspect of practical work in science including:

- how to do an activity;
- how to source equipment or materials;
- hazards and risk assessments associated with chemicals, equipment or procedures;
- how to dispose of used or redundant materials; and
- checking whether a particular practical activity is permitted.

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11. Figure 2 gives the number of helpline calls we have taken over the past five years. On average 84 per cent of the total number are from secondary schools.

<i>Year</i>	<i>No of helpline calls</i>	<i>No of calls from secondary schools</i>
2000–01	4,997	4,148
2001–02	5,396	4,533
2002–03	6,397	5,373
2003–04	6,618	5,560
2004–05	6,519	5,476
2005–06	6,836	5,810

Fig 2: Calls to the CLEAPSS helpline.

12. We attribute the increase in number of calls in part to a decrease in experience and expertise of science teachers. Indeed, around a sixth of our calls every day are from teachers or technicians who are unsure whether an activity is still allowed. In 2005 we were commissioned by the Royal Society of Chemistry to look into teachers' perception of substances and materials which could or could not be used in schools—*Surely that's banned*<sup>1</sup>. This report confirmed teachers' and technicians' levels of uncertainty and concluded that:

“there are significant misunderstandings on the part of teachers and technicians about the chemicals and scientific activities which are banned in secondary schools and some teaching is inhibited by unjustified concerns about health and safety”.

The report's conclusion goes on to say that:

“The lack of resources to enable schools to use some of the chemicals and approaches is a matter of concern. An equally worrying revelation is that schools do not feel they have the time to undertake many of the activities included in the survey . . .”.

13. It is clear that science teachers continue to use practical work with pupils. However, CLEAPSS is aware that the amount and variety of practical work is falling because of limits imposed by:

- teacher expertise and experience;
- resources including poor quality labs (see below);
- technician support (see below);
- concerns, real or perceived, over health and safety;
- concerns over manageability of practical work with large classes; and
- apparently-reduced curriculum demand.

The reduction in variety was referred to in paragraph 7 and is in part a consequence of teachers following published or department-produced schemes of work. In addition we know that teachers undertake fewer of the more spectacular or memorable demonstration practicals. Feedback indicates that many teachers no longer know how to do such demonstrations successfully and are unable to access, either within school or beyond, instructions and guidance on performing the demonstration and getting the most from it for the pupils.

14. Concerns over health and safety often feature in our discussions with both teachers and technicians. However, as we make clear in our publications and on our courses, science teaching is safer than most other activities undertaken in schools. There is hugely more risk of injury in sports activities than anything done in a science lab. Additionally, the principle of risk assessment requires teachers and technicians to assess risk to health and safety using the wealth of relevant information and guidance published by CLEAPSS and others. Thereafter, in the main, all previously-used practical activities can be undertaken with pupils, albeit perhaps adjusted by reducing the concentration or amount of chemicals used or adopting sensible safety measures such as wearing eye protection. Health and safety concerns are a real constraint in only a tiny number of practical activities, and, even for these, CLEAPSS offers advice on suitable alternative chemicals, equipment or procedures.

15. Teachers also report concerns over perceived problems in conducting practical work with large classes of pupils. These are generally expressed in conjunction with concerns over unpredictable or unacceptable pupil behaviour or fears of litigation because of inadequate supervision, in the event of an accident or injury to a pupil.

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16. An unforeseen consequence of coursework at GCSE has been to reduce to the barest minimum, the type of assessed practical investigation given to pupils. A desire to ensure that such investigations can be both rigorously assessed and enable candidates to do their best has meant that schools choose only those known to work well and conform to certain specifications. In practice this has led to perhaps as few as 10 different investigations forming the bulk of science GCSE coursework throughout the country. A focus on these and on the need to cover the GCSE syllabus is reported as leaving little room or time for other practical work. Other evidence<sup>2,3</sup> suggests that, more generally, examination work has reduced the willingness and/or ability of teachers to develop and use a wide range of practicals.

#### THE CONDITION OF SCHOOL LABS

17. In 2004 CLEAPSS was commissioned by the Royal Society of Chemistry to research and report on secondary science laboratories, resources and budgets in maintained schools in England<sup>4</sup>. At that time science teachers reported the need for one additional laboratory per school—a shortfall of some 3,518 laboratories. The condition of school science laboratories is summarised in Figure 3. The survey also revealed that 36 per cent of preparation areas were described as good or excellent with 21 per cent described as poor.

<i>Description of lab condition</i>	<i>Number in sample</i>	<i>per cent in sample</i>	<i>Number estimated for all maintained schools in England</i>
Excellent	280	5%	1,315
Good	1,641	30%	7,770
Basic (uninspiring)	2,262	41%	10,695
Unsafe/unsatisfactory	1,386	25%	6,560
Total	5,569	100%	26,340

Fig 3: Results of a survey of lab condition (taken from *Laboratories, Resources and Budgets*).

18. The figures for laboratories indicate that pupils are in unsafe/unsatisfactory or basic/uninspiring labs for 65 per cent of their science time in school. This figure does not include the 13 per cent of time that pupils were taught science out of a laboratory.

19. The report also makes clear that considerable funding would be required to improve all laboratories and associated preparation areas to a good standard. The report suggested that for labs alone this figure would be in excess of £1.2 billion.

20. Figure 4 provides data, drawn from the report, on the quality of labs in different schools. Specialist science colleges and those specialist schools which have some form of restricted entry have a higher proportion of labs judged as good or excellent (38.5 per cent and 39.3 per cent) compared with comprehensive schools (33.9 per cent) and even grammar school (34.9 per cent). Secondary modern schools fare the worst with only 25.6 per cent of their labs judged good or excellent.

21. The same data show that the quality of lab provision does not vary much between 11–16, 11–18 and 14–18 schools (35.7; 33.9; 33.9 per cent good or excellent).

22. Voluntary-aided schools have the least labs judged good or excellent (28.7 per cent) but also the least judged unsatisfactory/unsafe (20.6 per cent). However, although these variations will be important at the level of individual schools, in general, science laboratories in schools are too often of a low or basic quality. These are unlikely to convey to pupils the sense that science is an exciting and invigorating 21st century school subject.

23. CLEAPSS regularly receives calls which are to do with refurbishment of laboratories indicating that, since the above report was published, schools and local authorities have been improving at least some laboratories and preparation rooms. It is clear, though, from our conversations with teachers and technicians that schools which have a full suite of good labs and preparation areas are far from the norm. Also clear is that some of the new or refurbished labs are not very satisfactory.

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	<i>Laboratories</i>		<i>Unsatis/Unsafe</i>	<i>Basic</i>	<i>Good</i>	<i>Excellent</i>
	<i>No</i>	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>
Overall data*	5,569	100	24.9	40.6	29.5	5.0
<b>Type of school</b>						
Comprehensive	3,363	100	25.0	41.1	29.1	4.8
Grammar	255	100	24.7	40.4	29.8	5.1
Secondary Modern	185	100	26.5	48.1	23.8	1.6
Spec science	965	100	23.9	37.5	31.7	6.8
Spec non-science	740	100	25.9	40.8	28.8	4.5
Spec restricted	56	100	17.9	42.9	35.7	3.6
<b>Age groups</b>						
11–16	1,805	100	26.5	37.7	29.3	6.4
11–18	3,157	100	23.6	42.5	29.9	4.0
14–18	286	100	29.0	37.1	25.9	8.0
Other—Middle	124	100	23.4	37.1	33.9	5.6
Other—Secondary	197	100	24.9	44.2	26.4	4.6
<b>Status of school</b>						
Community	3,980	100	25.7	38.7	30.3	5.2
Foundation	687	100	24.7	43.1	27.2	4.9
Voluntary controlled	137	100	27.0	30.7	39.4	2.9
Voluntary aided	753	100	20.6	50.7	25.5	3.2

Fig 4. Quality of labs by type of school (taken from *Laboratories, Resources and Budgets*).

\*Responses from some types of school were so insignificant that they have been excluded from all except the Overall data figures, hence totals may not exactly tally.

<i>No of schools surveyed</i>	<i>Total No of labs</i>	<i>No refurbished</i>	<i>No newly built</i>
370	2,921	681	315

Fig 5. Unpublished data from current CLEAPSS survey on lab refurbishment and new build.

24. The data in Figure 5 are taken from a new, as yet unpublished, report by CLEAPSS for the Royal Society of Chemistry on new and refurbished labs. It suggests that over the period 2000–05 the rate of refurbishment of science labs was around 4.7 per cent per year and the rate of new build around 2.2 per cent. Respondents to the survey have judged 29 per cent of the refurbishment or new build to be unsatisfactory or poor, which is of some concern. The other labs were judged to be good or excellent. Although the data do not combine easily with those in Fig 3, they do suggest that the quality of labs is improving slowly.

25. An emerging science accommodation issue is the lack of ventilation in laboratories, prep rooms and chemical storerooms. For a laboratory being used by 30 or so pupils, having windows which for security and heating issues are not easily opened the atmosphere becomes hot and stuffy, especially if the Bunsen burners are lit. As well as being uncomfortable such conditions mitigate against practical work, do not foster a positive perception of science and may generate poor pupil behaviour.

26. Technicians also frequently work in an enclosed prep room with little or no natural daylight and poor or non-existent ventilation. The DfES publication *Science Accommodation in Secondary Schools*, BB80,<sup>5</sup> gives guidance on accommodation needs but this is not always followed.

#### RESOURCES FOR PRACTICAL SCIENCE

27. The survey of 2004 (*Laboratories, Resources, and Budgets*<sup>4</sup>) compared the funding for science with that suggested by the Royal Society in 1997.<sup>6</sup> In 2004 the average funding for science in maintained schools was £9.89 per pupil, little more than the £9.40 reported in a survey in 1998.<sup>7</sup> In 1997 the Royal Society report suggested a minimum funding of £11.38 per pupil was needed to provide essential science equipment. This

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figure rose to £17.28 if desirable equipment is included. By 2004 these figures had been recalculated as £20.58 and £29.14 respectively.

28. The 2004 survey further separated funding per pupil into 11–16 and 11–18 schools. This produced figures of £8.78 per pupil in 11–16 schools and £10.66 per pupil in 11–18 schools. The Royal Society report was based on the needs of pupils in 11–16 schools only. Figure 6 illustrates these and other figures.

29. Figure 6 also clearly shows much higher spending on science in grammar schools than in other types of school. However, since all grammar schools are 11–18 this may well be a consequence of the need for higher spending to accommodate post-16 students. Even so, spending on science in grammar schools comfortably exceeds that for other 11–18 schools. Spending in community schools is lower than in schools of other status.

30. More generally, the enormous range in spending in all types of school is a surprise and is not related to type of school, age range of pupils and status. Overall it is safe to say that in 2004 funding for equipment needed for practical science was well below that suggested for essential equipment in 1997 and even further below the comparable figure in 2004. Resources for practical science are inadequate and must be a constraint on pupils being able to see and take part in appropriate practical activities in the course of learning and enjoying science.

	<i>Average sum total</i>	<i>Range in total sum</i>		<i>Average per pupil</i>	<i>Range in sum per pupil</i>	
All schools	£10,560	£1,030	£40,000	£9.89	£0.64	£71.43
Comprehensive	£9,962	£1,030	£36,500	£9.32	£0.64	£20.61
Grammar	£14,851	£6,129	£31,500	£16.20	£8.59	£31.34
Secondary modern	£7,520	£3,250	£14,000	£9.76	£6.00	£22.22
Spec (all ability)	£11,584	£1,400	£40,000	£10.00	£1.08	£71.43
Other	£8,648	£2,000	£17,056	£9.96	£3.85	£18.36
11–16	£7,683	£2,000	£19,000	£8.78	£2.96	£18.47
11–18	12,374	£1,030	£40,000	£10.66	£0.64	£71.43
14–18	£12,194	£6,000	£22,600	£9.17	£4.62	£14.95
Other	£10,237	£5,000	£22,000	£9.99	£6.33	£15.94
Community	£10,267	£1,030	£36,500	£9.49	£0.64	£25.00
Voluntary controlled	£11,495	£3,500	£18,000	£11.40	£5.00	£18.95
Voluntary aided	£10,307	£2,000	£40,000	£10.78	£3.33	£71.43
Foundation	£12,003	£1,400	£26,000	£10.64	£1.08	£28.50

Fig 6. Average science department allocation in 2003–04 (From *Laboratories, Resources and Budgets*).

#### THE PROVISION AND USE OF LAB TECHNICIANS

31. Around 2,000 science technicians attend CLEAPSS training courses every year, demonstrating a commitment by technicians to improving their professional practice and by schools to support them. Around two thirds of the calls to the helpline are from technicians, although it should be recognised that technicians have more flexibility in getting to a telephone during the day and will sometimes phone on behalf of teachers. Feedback from these contacts and other work which CLEAPSS undertakes confirms the following.

- Many schools have insufficient technicians or technician time to meet the recommendations for technician support in the Royal Society/Association for Science Education *Survey of science technicians in schools and colleges*.<sup>8</sup>
- The majority of technicians work part-time, generally term time, and school hours. This impacts significantly not just on the time to do the job but also on the role science technicians can take within the school and recruitment of young people into the profession.
- Pay is invariably low.
- Around half of science technicians never attend science department staff meetings and a third do so only occasionally. This excludes them from general communications, discussion and the opportunity to take part in and influence department decisions.
- The great majority of science technicians are committed to their work.

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32. Calculating how many technicians are needed to service the needs of a science department is complex, although CLEAPSS has, in guide L228,<sup>9</sup> produced a plan for any school to calculate its needs reasonably accurately. However, as reported in *Supporting Success: science technicians in schools and colleges*,<sup>10</sup> and by technicians and heads of science, the provision of technicians is often considered to be inadequate. The current provision for science technicians is likely to become even less adequate as the science education community, including schools, teachers and those devising new and more interesting science curricula, try to remedy concerns over the limited amount and range of practical work being undertaken in school science.

33. There is no simple answer to the issue of current science technician working hours. It is clear that part-time working suits many but it seriously restricts the capacity to undertake annual or termly maintenance and servicing of laboratories and stores. These sorts of activities are often most effectively undertaken when a school is not in session; this is clearly not possible if the technician is not there either. Time constraints also limit technicians' opportunities to develop new equipment, to repair that which is broken or to try new practicals. Additional constraints are imposed where technicians are required to undertake clerical tasks rather than those which require technical expertise. Working hours which do not extend much beyond the school day also mitigate against technicians attending science department meetings.

34. Currently the ratio of males to female technicians is 1:3 and around three quarters of technicians are over 40 years of age.<sup>4</sup> These facts are linked to the part-time nature of most jobs, the relatively low pay and to the lack of any well-considered career structure with associated training and accreditation programme. It is important that not only the issue of inadequate numbers of technicians is considered but also the provision of a suitable career structure and training to encourage younger people into the profession. At the moment younger people working as technicians inevitably regard such work as stop-gap rather than the start of a fulfilling career.

35. All of the points made in the previous paragraphs also contribute to the relatively low status enjoyed by many science technicians in schools. The fact that most technicians do not attend science department meetings further contributes to a sense of being less valued than others in the school. For very little additional money schools could ensure that at least one science technician has sufficient paid hours to be included in after-school science department meetings.

#### REFERENCES

<sup>1</sup> *Surely that's Banned?* A report for the Royal Society of Chemistry on Chemicals and Procedures Thought to be Banned from Use in Schools; October 2005; Available at [www.rsc.org](http://www.rsc.org).

<sup>2</sup> *Is teacher innovation on the verge of extinction?* I Kinchin, *School Science Review*, December 2004, **86** (315) pp 16–18.

<sup>3</sup> *Teacher innovation* A letter from M Ellse, *School Science Review*, September 2005, **87** (318) pp 9–11, Association for Science Education.

<sup>4</sup> *Laboratories, Resources and Budgets.* A report for the Royal Society of Chemistry on Provision for Science in Secondary Schools; April 2004. ISBN 0-85404-384-5. The Royal Society of Chemistry, Burlington House, Picadilly, London W1J 0BA.

<sup>5</sup> *Science Accommodation in Secondary Schools*, BB80, revised 2004, DfES.

<sup>6</sup> *Science teaching resources: 11–16 year olds*, 1997, The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG.

<sup>7</sup> *Science teaching resources: 11–16 year olds.* The survey findings. P Ramsden, *Education in Science*, 180 (November 1998), pp 19–21.

<sup>8</sup> Survey of science technicians in schools and colleges, 2001, Royal Society/Association for Science Education, available at [www.royalsoc.ac.uk](http://www.royalsoc.ac.uk) and [www.ase.org.uk](http://www.ase.org.uk).

<sup>9</sup> *Technicians and Their Jobs*, Guide L228, December 2002, CLEAPSS, publicly available at [www.cleapss.org.uk](http://www.cleapss.org.uk).

<sup>10</sup> *Supporting success: science technicians in schools and colleges*, January 2002, Royal Society/Association for Science Education, available at [www.royalsoc.ac.uk](http://www.royalsoc.ac.uk) and [www.ase.org.uk](http://www.ase.org.uk).

The CLEAPSS® School Science Service is an advisory service supporting **practical** science (and technology) in schools, colleges, etc. It is largely funded by subscriptions from members. At the present moment every one of the 180 local authorities in England, Wales, Northern Ireland and the various islands is a member and

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hence all their schools have free access to CLEAPSS services. The vast majority of independent schools, post-16 colleges and teacher-training establishments are associate members, as are many curriculum developers, field study centres, hands-on museums and learned societies. There is a particular focus on health and safety.

CLEAPSS produces a large number of publications for members, ranging from termly newsletters for primary and secondary schools, a 1000-page *Laboratory Handbook*, *Hazcards*,<sup>®</sup> *Recipe Cards* and many leaflets and booklets. Much of this is now available on CD-ROMs. The members' takes about 6,800 calls per year. CLEAPSS also runs about 210 courses per year, mostly 1-day. We are represented on several committees of the British Standards Institution and maintain a close dialogue with the Health and Safety Executive, the Qualifications and Curriculum Authority, professional bodies and others with an interest in science education.

### Examination of Witnesses

Witnesses: DR MICHAEL DAY, Executive Director of Initial Teacher Training, DR STEPHEN BAKER, TDA Strategy, Training and Development Agency for Schools; DR DEREK BELL, Chief Executive, Association for Science Education and MR PHIL BUNYAN, Director, Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS), examined.

**Q199 Chairman:** Thank you very much for coming to talk to us. Will you introduce yourselves? If you have a brief opening statement, make that as you wish.

*Dr Bell:* I am Dr Derek Bell, chief executive of the Association for Science Education. I would like to make a couple of short points.

*Mr Bunyan:* My name is Phil Bunyan. I am the director of CLEAPSS, an organisation that supports school science.

*Dr Day:* I am Dr Michael Day and I am an executive director for Initial Teacher Training at the Training and Development Agency.

*Dr Baker:* I am Stephen Baker and I too work at the Training and Development Agency.

*Dr Bell:* I want to re-emphasise two points which are slightly outside the scope. The first one is the importance of primary science. I think it is fairly well recognised that over the last 10 or 15 years primary science has been a success but, as we heard in the earlier round of evidence, there are dangers that we are going to lose some of the gains that we made. If we lose those, anything we do at secondary key stage three and upwards is not going to be on a firm foundation. I think it is important to remember that. The second one is I always get very worried and depressed, in a way, when we get into some of these conversations because it is the negatives that tend to come out. We need to remind ourselves from time to time that there is an awful lot of very good work going on out there and there are teachers engaging students every day of the week, as we sit here. It is important that we remember that. One of the challenges is not introducing something new but spreading that good practice more widely.

**Q200 Chairman:** To encourage you, we have visited two schools where we did see some excellent teaching going on and some very enthusiastic teachers and students. We have seen the good side.

*Dr Day:* I would like to make one quick remark. We have had an interesting discussion about the Student Associates Scheme. I would not want people to be left with the impression that there were problems with that scheme which we are administering. It is useful for the Committee to know that the earlier scheme was a pilot and we are running it in certain areas but we have done a lot of work to expand the scheme. It is now five times bigger than it was three years ago and that means we have a much bigger national coverage. We have a lot more people involved in it. Something like 2,500 science and maths students are involved in the Student Associates Scheme. It is really a very important part of our work and it is much more available than it was. As a result of evaluation I think it is much higher quality than it was two or three years ago.

**Q201 Chairman:** Dr Bell, in your evidence you suggest that the recent changes in the Ofsted inspection regime will restrict the amount of evidence available on science teaching. Do you believe that Ofsted should revert to the previous system?

*Dr Bell:* Not necessarily, no. Reverting to the previous one would be a retrograde step. The point about the new regime is that the amount of reporting on science specifically and any subject has been removed from most school inspections. The overall surveys that they used to do in terms of science have now been reduced to 20 or so schools a year. If you are only going into 20 schools a year, it is not giving you a good evidence base. One of the things we have found in preparing for this inquiry and for other occasions as well is that the sort of evidence we would want to have access to does not appear to be available. A major area, which is what the Ofsted database did provide, is going to be lost. The substantive point is about how are we going to know what is going on out there on some firm based evidence. We have lots of changes coming in at the



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moment. How are we going to monitor the impact and effects of those changes if we do not have a way of monitoring it?

**Q202 Chairman:** I suppose the question is will it be possible to identify poor science teaching in individual schools under the new inspection scheme.

*Dr Bell:* Broadly speaking, no.

**Q203 Chairman:** How adequate will the new, broader subject specific reports be given that the data will be derived from only a handful of schools?

*Dr Bell:* If you only have a handful of schools you need to extrapolate that. It just becomes almost meaningless. It is like me quoting an example of my own children at school. You cannot translate that to what is going on all over the country.

**Q204 Lord Taverne:** I want to come back to something we have already explored with the previous witnesses. Teacher recruitment initiatives appear to focus predominantly on recent graduates. Do you think enough effort is being expended on attracting people mid-career from other professions or following a career break. Following up some of the written evidence you have given, do you still feel that this can happen and be effectively pursued without some sort of pay differential?

*Dr Day:* We would be disappointed if that was the view of the select committee, that our marketing advertising was directed at recent graduates because we have gone to great lengths to try to market our teaching to a much wider group of people. We are very careful to segment all the different types of people who might come into teaching and think of a way to attract each of those groups into teaching. At the moment we estimate that about 85 per cent of the money we spend on recruiting people into teaching is targeted at people who are already in jobs, who are looking for a second job. One of the things that was most pleasing for us last year was that teaching was voted the most attractive second career by a survey of old graduates. Teaching hovers around being the most attractive first career. Often PR and marketing just pips us but sometimes we slip into the lead. We are now very clearly the career of choice for career changers. The second part of your question was dealing with two different aspects. One of them is about people in mid-career coming into teaching and the second is about people returning from career breaks. We had an interesting discussion in the first half about people in mid-career. John Bangs was kind enough to talk positively about the graduate teacher programme which we very much targeted on career changers. This is an opportunity for people to move into school and to be employed as a teacher whilst they do their training. Six years ago only about 30 people were doing that. We have now pushed that up

to 500 people a year training to be science teachers through the graduate teacher programme. We are constantly offering opportunities for more people to follow that particular route. On the career break people, we spend a lot of time trying to keep track of people who have left teaching on career breaks and are interested in coming back. We have a three prong strategy. First, we run a database and a telephone help line. If anybody wants to return, they can ring that help line. Second, we have a magazine which we publish and send to anybody who expresses an interest in coming back. Stephen has a copy if anybody would like to see that. That magazine is very heavily targeted at science and maths teachers that have taken career breaks. The front cover is almost always targeted at science. We offer courses to people who want to return to teaching who feel they need some refreshment before they go back into the classroom. We think at the moment about 10,000 people are career break people going back into the profession. That is about a quarter of people entering the profession. Of those, about a fifth go on our courses to upgrade their skills if they have been out of the classroom for a while. They get a better understanding of ICT, a new subject that is going to be taught, and new approaches to behaviour management. We are working very hard. For those courses people get bursaries and child care allowances, so we go a long way to encourage people who have had a career break to think about going back into teaching.

*Dr Bell:* Going back to the question about whether people should just be allowed to come into teaching, you would not expect that if you were going to be a doctor. You have to demonstrate that you can do it. It is more than simply knowing information. That is important. Some years ago I was part of the graduate teacher scheme and other developments. There are assessment only routes which are a fast track process for getting in. When we are talking specifically about science, some of the schemes like Teach First tend to be generic. Maybe one of the things that we have to do in the science teaching world is to start to link into those schemes more closely and focus the science people and help and give them support through science.

**Q205 Baroness Perry of Southwark:** I want to come to the subject of CPD. At the moment we do not have any culture of entitlement to CPD. Is that something in your various roles you would like to see happen? The amount of CPD that takes place seems very large but when you look at the proportion of the teaching profession that engages in any one year in CPD it is quite small. Should there be entitlement? If so, is this a job for the government or should the government be placing an obligation on teachers? What are your views about that?

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*Dr Baker:* It is less an issue of creating a culture of entitlement or obligation and more an issue about a culture of professionalism. The TDA, for example, has been working on a review of teachers' professional standards to look at the kinds of standards that teachers should meet at different stages of their careers and at what stage they should show examples of not only their own professional development but how far they have been able to develop expertise in other subjects. In the past, the development of professional standards was done at very different times and the standards for qualified teacher status, for induction after teachers have taught for a year and for threshold were all developed at different times for very different purposes. There was no coherence and no clear progression as teachers went through these stages of their careers. These requirements now have been built into the standards so that it is clear for teachers what they have to do in order to progress in their career. We know from the General Teaching Council of England survey of last year that more than half of teachers associated CPD with career progression. They say that they see that as a key reason for their professional development.

**Q206 Baroness Perry of Southwark:** Is there not a danger in that? Are you not saying that only those who want to move out of the classroom are the ones who are interested in CPD? What we want are good science teachers who are kept up to date in their subject and in the pedagogy to be kept in the classroom.

*Dr Baker:* These are standards for classroom teachers but at different stages in their career within the classroom.

**Q207 Baroness Perry of Southwark:** You said it was linked to their ambition in career progression.

*Dr Baker:* Yes, but career progression still working as classroom teachers. For example, teachers who go through the threshold standards have a responsibility perhaps overseeing the development of other teachers, perhaps newly qualified teachers in the school, but are themselves still classroom teachers who perhaps have some other management responsibilities within the school as heads of department and so on.

**Q208 Baroness Perry of Southwark:** How much of this is anything to do with keeping you up to date in a subject?

*Dr Baker:* It is very substantially tied to keeping up to date in the subject. The new review of standards has at its centre a requirement that teachers remain up to date and show evidence of remaining up to date with the new developments in the pedagogy and subject knowledge.

*Dr Bell:* When you talk about CPD, it seems to me that entitlement and responsibility come together. The responsibility rests with the individual who is supposed to show commitment to keeping up to date as part of the profession. That was one of the drivers behind ASE introducing the Chartered Science Teachers Scheme because that does not simply say, "You have it today" like my PhD 20 odd years ago. I cannot remember what it was about. The Chartered Science Teachers Scheme says you have to recommit and reassess that every five years, so you have to keep up to date as part of that process. The responsibility goes into the school and into national and local government. Each one has to play a part in supporting that CPD. You make a statement about an entitlement but how does that then get put into place? It is the three levels of responsibility that have to encourage that.

**Q209 Baroness Perry of Southwark:** Is there not a financial issue here as well? We visited the Science Learning Centre and saw the excellent courses that were being put on there but the teachers we spoke to who were on the courses were all quite clear that, if they had not had bursaries, their school would not have been able to afford to let them come. Those bursaries are coming to an end. What are the prospects after that?

*Dr Bell:* They are fairly bleak. Finance does come into it. It is not just the cost of the courses and so on. That is certainly one factor. We have to be careful. CPD comes in a number of forms. To expect that you do your CPD by going to the National Centre or wherever is not the way it is. You will go there, one hopes, on a fairly regular basis but there are other ways of keeping up to date. That is where the personal commitment comes in. You do that as part of your every day work effectively to keep right up to date and make those links.

*Dr Day:* I agree. From the agency perspective, our work in CPD is now very much focused on helping schools consider what makes good CPD and how best to spend their money so that within the resources they have they make the best use of that. A lot of that is about tying CPD much more closely to teachers' professional development. We are keen that schools become much more expert at working with teachers to identify what CPD they need particularly to help with their effectiveness as teachers and think about the best ways in which they can fund that and provide that. The entitlement argument can be reduced to a sort of tick box where you can say, "Yes, I have done my 20 days." The 20 days are not necessarily tied very closely to what the teachers really need to improve their performance in the classroom. We are very keen that we develop schools' expertise a lot more in working with teachers to assess the precise interventions with each teacher which would allow

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them to improve their work with children and young people.

*Mr Bunyan:* There is a notional entitlement already to CPD. The school closure days were originally designed for that purpose. From my perspective, they are rarely used for subject specific improvement. It is general CPD. There must be some avenues to explore there to persuade schools to look more closely at the subject needs of teachers as well as the generic stuff.

**Q210 Baroness Sharp of Guildford:** When we were discussing this earlier, Mr Bangs suggested that the GTC scheme of the ladder of accreditation, which is a more general scheme of accreditation, was one that was attractive. Another possibility is that when you do CPD you earn credits towards, let us say, an MSc or something like that. Do you think a national scheme that encouraged teachers to do CPD because they would earn credits towards higher degrees or something like this in the process would encourage them to give up their own time as well as the school time? This was something that came up when we went to the National Science Learning Centre.

*Dr Day:* That is a very valuable contribution. We need to look very carefully at how we can encourage teachers to see their professional development across a long timescale. We are very encouraged that a lot of universities have been looking at changing their PGCE courses, their initial teacher training courses, to give credits on those courses for Masters degrees. They are revalidating their courses within their universities to make substantial chunks of them Masters level rather than not Masters level. That is very good because people are embarking on a Masters course in their initial teacher training and they then have the basis to add to that through doing diplomas, certificates or other pieces of work over the first two or three years of their career, which builds up to a Masters degree. A number of those universities are working with their local authorities to look for ways in which the training on the induction year can contribute credits as well towards a Masters degree. We are very keen on doing that and looking at how we can link the money which the TDA gives to universities for professional development qualifications to reach Masters degrees can all be linked together in a continuous programme for teachers. Interestingly, Stephen mentioned earlier the teacher standards. A number of universities now are looking at the standards which teachers are expected to reach after about five years to say, "Can we construct our Masters degree courses so that teachers can use them to demonstrate that they have met those standards?"

*Dr Bell:* The developments where the different routes, the Teaching Learning Academy, the GTC scheme, are starting to link together are very welcome. To create a national scheme you have a problem. A

significant number of universities still do not always accept credits from one to another. That is something you have to crack. If you have credits, they have to have universal currency.

**Q211 Baroness Sharp of Guildford:** You have to be able to mix and match distance learning and on site learning and so forth.

*Dr Bell:* Absolutely. It is fair to say that a lot of teachers do not particularly want a maths degree. What they want is professional training which is recognised in some way that meets their needs for teaching children in their classrooms.

*Dr Baker:* To add a bit more information on the postgraduate professional development programme, it is the only one that the TDA funds. It is our only funding stream. That is a scheme whereby normally universities or HEIs work in collaboration with local authorities, schools and federations of schools to develop exactly these types of models for professional development, often based around subject knowledge and subject pedagogy, where they work very closely with the schools to find out exactly what the schools' and the teachers' priorities are and then develop Masters level and accredited programmes around that. We certainly found, when we first developed this programme from a previous scheme, it led to a significant expansion in the number of schools, local authorities and higher education institutes that wanted to be involved in it. This partnership working, which most of the research and evidence says is the most effective form of teacher CPD, does seem to be something that we can expand through this type of programme.

**Q212 Baroness Sharp of Guildford:** Do you think the scheme could be used to help retrain some teachers? We know that a lot of biology teachers are supposed to be teaching physics and so forth so would that help with the process of transition there?

*Dr Day:* Indeed. One of the recommendations of the report published after the budget on science teaching made that specific recommendation, that we should develop an accredited diploma for people who wanted to expand their subject knowledge. We are working very closely with the National Science Centre at the moment on how we can work up a proposal for that kind of diploma. We think it is a very good idea.

**Q213 Lord Howie of Troon:** As you know, there are new GCSE courses coming up quite soon, before the end of this year. Have teachers been given enough time and help to make them able to teach these courses properly? Secondly, can they do it without diminishing or dumbing down the real science content of the courses?

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*Dr Bell:* The answer to the second question is yes. It is not the way it is written in the curriculum or whatever; it is what happens in the classroom. If the important thing is to engage the students in what you are doing, the new courses should be a move in that direction. The rigour has to be there. I am a biologist so I will use a biology example. If I am teaching genetics and I start talking about Mendelian crosses, half the class will get switched off.

**Q214 Lord Howie of Troon:** You have got to me already.

*Dr Bell:* Exactly. If I start to talk to you about genetic counselling, about how a disease might be passed on from parents to children, more children are likely to be interested. How does that happen? Then you start to get into the genetics and how the genes work and all of that. You start to engage. The answer is yes, very unequivocally, providing we stick to the rigour and I think the majority of teachers will do that.

**Q215 Lord Howie of Troon:** Do you all agree?

*Mr Bunyan:* Absolutely.

**Q216 Lord Howie of Troon:** Dr Bell, in your written evidence you seemed rather critical of teaching to the test. Do you think that testing should be much reduced?

*Dr Bell:* Broadly, yes. In a sense, teaching to the test has always happened.

**Q217 Lord Howie of Troon:** I remember it well.

*Dr Bell:* The climate of that was very different, certainly as I recall it. To some extent, what seems to have happened is that, in a lot of the tests that we have now, the leeway for whether things are right or wrong is much reduced, particularly when you are talking about key stage two which is end of primary and key stage three which is the 14 year old test. If you do not have a particular word, it is wrong. Inevitably, we start to get to a stage where pupils are taught those particular words to use and therefore that restricts the teaching. If you allow a little bit more leeway in the assessment process, that allows for a little more innovation in the teaching and more flexibility. Students then are putting down what they know, not finding out what they do not know.

**Q218 Lord Howie of Troon:** I seem to remember in the very old days that science tended to be about right and wrong. Was it not?

*Dr Bell:* That is one of the things we have tried to address through the new key stage four programme of study. We all know as scientists that it is not right and wrong.

**Q219 Lord Howie of Troon:** It is kind of.

*Dr Bell:* There are certain things that are more likely than others.

**Q220 Lord Howie of Troon:** You are talking about uncertainty.

*Dr Bell:* Absolutely. One of the things that does happen is, because the impression is that or that, students do not get the chance to suggest alternatives. One of the things about science is that there are alternative explanations. The evidence then leads to one which brings a consensus. That is what part of the science community is about. We kill that so that you get students who go through and hear that photosynthesis is this in year six. That is top primary. They get photosynthesis in year eight and it is slightly different. When they get to year ten, "Forget what you did because it is like this." When you get to A level and beyond, we know it is incredibly complicated but it is this black and whiteness that is self-defeating. The assessment process tends to encourage that way of thinking.

**Q221 Lord Howie of Troon:** I am an engineer, by the way, and we tend to be right most of the time.

*Mr Bunyan:* Going back to the last question, has there been sufficient support for teachers, the Secondary National Strategy started supporting teachers almost directly just over a year ago. Although you cannot quantify "sufficient" there has been quite a lot of support. I do not suppose there is ever enough but it has been going on for some time.

**Q222 Lord Howie of Troon:** You are pleased with it?

*Mr Bunyan:* Yes.

*Lord Howie of Troon:* That is sufficient in my eyes.

**Q223 Baroness Sharp of Guildford:** We have the Education Bill before the House at the moment. One of the aspects of the Education Bill is that schools should make available to students the double award science. Do you think this is going to help in terms of encouraging students to go on with science through to A level? My Conservative colleagues are anxious also to see the ability of students to take three separate sciences and they have an amendment down to that effect. I would be interested to hear your response on how far that would be helpful.

*Dr Bell:* From September 2006, under the new GCSE arrangements, double award in effect no longer exists. What students will be allowed to do is to take the equivalent of two GCSEs and, in a lot of the schemes, there is a core plus an additional. The requirement of the entitlement is something that is important because, when it was double award, if you did the science you did the double award which is the equivalent of two GCSEs. I do know of head teachers who were starting to look at the new key stage four

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arrangements, saying, "All we have to do then is to offer them a single GCSE in the core science", so you ran the risk of losing science for a large number of students. To make it an entitlement that all students have the double equivalent is important. The triple science arrangement depends where you come from and what you are trying to achieve. For students who want to do science they can go on to do science if they have the equivalent of three GCSEs and that time available. Clearly it is a better preparation but for other students that is not what they would want. Therefore, it does not have to be made an entitlement for all students. It certainly should be available and a lot of schools already do try to make it available by different means. Under the new arrangement it will be even easier to do that.

*Dr Day:* The introduction of triple science is going to put a big pressure on schools to recruit physics and chemistry teachers to be able to teach children these subjects. As an agency, we have been giving a lot of attention to how we can increase the number of physicists and chemists going into teaching and how we can expand our subject enhancement courses where biologists and other scientists can take a six month course to increase their subject knowledge to become specialist in physics and chemistry. Over the last three years we have doubled the number of physicists going into teacher training but we want to do a lot more than that in preparation for introduction of triple science to make sure there is a proper supply of physics and chemistry teachers going into schools.

**Q224 Chairman:** You are optimistic that the government's targets for the increased numbers of science teachers can be met?

*Dr Day:* We are optimistic and we are doing a lot of work to put them in place, yes, on the recruitment front. Through subject enhancement the government is likely to give the agency quite a lot more resource to increase subject enhancement courses for physics and chemistry quite substantially.

**Q225 Lord Mitchell:** I suspect I could answer this question and I suspect I know how you are going to answer it but I will ask it all the same. How concerned are you by the significant fall in the number of teachers taking your courses? What are the reasons for this decline and do you expect it to impact adversely on the teaching of practical science in schools?

*Mr Bunyan:* We are very concerned about this. We train large numbers of technicians but we are very conscious that they do not have the voice in the department to pass that training on, except in very specific instances. To some extent a lot of our good training gets lost. The technicians value and enjoy it but they do not make use of it and it does not impact

on teaching. What are the reasons for the decline? Over the last five or ten years there has been a culture whereby the teacher needs to be in front of the children. Although that is true, I do not think it is as exclusively true as some teachers and head teachers believe it to be. There is a bit of flexibility needed there. I acknowledge that it costs a lot of money to take teachers out of the classroom and replace them. Of more importance is the quality of the supply teacher that goes in. It is the chaos left behind that is a major issue. I do not know how science departments handle that. In days of yore when I was first teaching we did it ourselves and therefore we did not have that problem. Yes, I am concerned about it. One of the consequences is that we are not redressing the narrowness of the practical work which pupils see and do. We have large numbers of teachers who are now approaching the twilight of their teaching career and, as they leave, they will take with them the expertise and experiences they have had. We have probably a generation of younger teachers for whom teaching science has been a process of teaching from a scheme of work written within the department or a commercially published scheme brought in, with little flexibility, little need to show initiative and develop their own way of teaching. The teachers who have done all that and who exercise some influence at the moment are going to leave and we will be left with teachers who have little experience of that. They will all end up doing the same narrow range of activities which we think is a serious problem and a big mistake.

**Q226 Lord Taverne:** Do you think there is scope for more teaching to be done using new media in some ways through DVDs, television programmes and e-learning or distance learning as a total concept? Do you think this is something which could be used more?

*Mr Bunyan:* Generally, yes, but from a science perspective we are worried that this becomes science by audio visual aid, by film clip. We would like to see youngsters getting their hands on equipment and feeling the sciences. We have a major concern that the new media will detract from science teaching at the same time as enhancing it.

**Q227 Lord Taverne:** Instinctively, do you feel that schools that use ICT, that are at the vanguard and pioneers in using it, would be leaders in science teaching as well?

*Mr Bunyan:* My experience is very indifferent on that. I do not think that is necessarily the case. In the past year we were looking for good science teaching using new media. We failed to find it. That was when I worked with the National Strategy. We had to commission it in order to be able to demonstrate it could be done. There really is a shortage so I do not

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think that science teachers are at the vanguard. I have seen wonderful new media used in religious studies.

**Q228 Baroness Platt of Writtle:** Is there a danger that science practical teaching can focus excessively on one-off spectacular experiments at the expense of open-ended investigative work which more closely resembles scientific research? Is there a conflict between experiments that excite students and those which teach them important skills?

*Mr Bunyan:* I do not think there is a danger that there will be a focus on the dramatic demonstration. Teachers are getting less and less experience at doing those dramatic demonstrations. One of the things we would like to do is increase teachers' willingness and experience of doing them. We would like to see more of those. I do not however think there is a conflict between that and investigative science because the national curriculum at key stage two particularly and three has focused very much on investigative science. The assessment of that has focused, particularly in the last three or four years, on that and we have seen great strides being made in teachers' willingness and skills in teaching investigative science. We have not yet seen those at GCSE where the investigations have become very formulaic, but I believe that the new national curriculum for key stage four might bring about that change too so that teachers can build upon what went before in key stage three and even earlier in key stage two. I see a bright future for investigative science and I would like to see a bright future for really good demonstrations too.

*Dr Bell:* We need to be clear why we are doing practical work of any sort. There is a danger that we do the practical work and that can be as off-putting as anything else. If it is about a particular skill you are trying to develop, you design the practical work to do that. If it is about a total investigation, completely open ended, you design it to do that. It is important that we bear that in mind when we are getting to this level of discussion and the same with the use of ICT. There is a danger that you do it by simulation, not using the test tubes or whatever, which is where you really get some of the excitement from.

**Q229 Lord Sutherland of Houndwood:** I wanted to ask a couple of questions about some of the constraints on practical science teaching. One, at least notionally, is worry about health and safety. We all worry about that. We know the stories about not taking people out of schools and so on. Is that constraining the use of practical science and do teachers really understand what the requirements of health and safety are?

*Mr Bunyan:* Yes, it is constraining. Secondly, do teachers understand? Probably not.

**Q230 Lord Sutherland of Houndwood:** What can we do about that?

*Mr Bunyan:* The Association for Science Education has had a programme called Fighting Back for a long time now. It includes writing to newspapers and that kind of thing but it is about fighting back. At CLEAPSS we have just produced a report that I referred to in my submission called *Surely That's Banned*. I have a copy if you would like to see it.

**Q231 Lord Sutherland of Houndwood:** That would be useful.

*Mr Bunyan:* We asked about 40 practical activities which might plausibly be banned but only two are banned, using benzene and crude oil. Teachers' responses suggested that some teachers thought all of the other 38 were banned by somebody somewhere but almost none of the respondents could produce any kind of document to demonstrate that they knew that. They just knew it. It is the power of myth and rumour and it is very hard to contradict. The ASE is taking a stance. CLEAPSS are taking a stance more positively. It is so well entrenched a process that we have to work at it over time.

*Lord Sutherland of Houndwood:* I think it would be useful to have a copy of the summary.

**Q232 Lord Taverne:** That document, which I have seen, did not paint too pessimistic a picture, did it?

*Mr Bunyan:* It was not awful, no.

**Q233 Lord Taverne:** There was rather less concern about the effect of it than one would have expected.

*Mr Bunyan:* I did check before I came today. About 40 per cent of last year's telephone calls to CLEAPSS were about safety issues. They were very much, "Can we do this? Is this banned?" I had two or three today. It is constantly on the go.

**Q234 Baroness Platt of Writtle:** It is good that they get in touch with you.

*Mr Bunyan:* Absolutely, yes, so we can say no.

*Dr Bell:* It is just the general culture about being risk averse and so on. Yes, you have to do your risk assessments and be practical in whatever you are doing but sometimes it needs a head of department or a head teacher to say, "Try it." Going back to the issue about teachers' ability to do practical work these days, there often is not time for them to try these things out quietly in their own time in the prep room, which used to happen an awful lot in the past.

*Mr Bunyan:* There is a very real fear of litigation, often unfounded. We would want to suggest that everybody who has some influence encourages schools to take on these rather spurious claims and go to court. We have been involved a couple of times in the last 12 months with these and, although we have

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got to court, the case has vanished before we got there.

**Q235 Lord Sutherland of Houndwood:** In relation to class sizes, the evidence from your organisation implied that class sizes were relevant to how manageable this is. Do you want to expand on that a little and how could we deal with it?

*Mr Bunyan:* I am quite ambivalent about this in some ways. Class sizes are a problem if you are not certain of the behaviour of the youngsters. We have already heard about poor behaviour being a major catalyst for teachers leaving the profession. On the other hand, we can probably all say we have seen classes of 35 doing practical work fine and dandy. It is not just class size; it is a combination of size and a number of untrustworthy youngsters in the class. Sometimes you can have five children in the class—I have seen that—and not be able to do anything successfully because they are all untrustworthy.

**Q236 Lord Sutherland of Houndwood:** In your evidence it was suggested that the use of money for refurbishing school science accommodation had not been all that wise and 29 per cent of the refurbishment and new build is unsatisfactory. Do you stick with that figure?

*Mr Bunyan:* Absolutely. The newest evidence is exactly that. I know the government has a project to build exemplarily but we have seen some of the specifications of science labs and frankly they are woefully inadequate.

**Q237 Lord Sutherland of Houndwood:** Have you been consulted?

*Mr Bunyan:* No, we have just seen them because we know somebody who had them but they are, as written, not good enough for anything. It looked like an administrative oversight.

*Dr Bell:* We have had the same experience in trying to link with things like building schools for the future, to address the science problem, but with no impact whatsoever.

**Q238 Baroness Platt of Writtle:** Even when you have met a minister?

*Dr Bell:* We have not met ministers about it. We try to do it through the building schools for the future team and we are not getting anywhere with that at all.

**Q239 Earl of Selborne:** How can the professional status, career structure and conditions of pay of school science technicians be improved?

*Mr Bunyan:* We produced this document which I will leave with you which opens up with an endorsement from Margaret Hodge, who was then Minister of State, and also Dr Ian Gibson, the chair of the House of Commons select committee. That is the answer. It

is a description of technicians, the work they do and the four or possibly five tier career structure which considerable implemented by schools. It needs taking on.

**Q240 Earl of Selborne:** You are doing training courses yourselves. Are they being well taken up?

*Mr Bunyan:* The training for technicians is being well taken up but their career structures are still woefully inadequate.

**Q241 Earl of Selborne:** The career structure is down to the head of the school?

*Mr Bunyan:* Often the head teacher, yes, who independently decides what salary to pay.

**Q242 Earl of Selborne:** What about using technicians more in a teaching role in practical classes, something like a higher level teaching assistant? Is that a practical suggestion?

*Mr Bunyan:* We think a lot of technicians would like to do that and some would use that as a stepping stone to becoming teachers which would be very good. Our biggest fear is that you cannot get two people for the price of one. If they are not being a technician, the technician's work is not being done. We just want to caution that head teachers who might be hard pressed for cash might see this as a way of getting two roles fulfilled. They will not. They will get probably less than half of both roles, but it is a good idea in principle.

**Q243 Lord Howie of Troon:** In the past there were no technicians. At one time you did get two for the price of one.

*Mr Bunyan:* What sort of past are we talking about here?

*Chairman:* Lord Howie, are you going back to the good old days or the bad old days?

**Q244 Lord Howie of Troon:** There were good days and bad days.

*Mr Bunyan:* We have had science technicians as long as I have had a career and they were well established when I started.

**Lord Howie of Troon:** Maybe it was another country.

**Q245 Lord Sutherland of Houndwood:** In Scotland I had the same experience.

*Dr Baker:* I had a science technician when I was at school.

*Dr Day:* Could I comment on the higher level teaching assistant? The HLTA is a form of TDA fund and is part of our agency's wider responsibilities for the school workforce. We have been piloting an approach for HLTAs who want to be specialists in mathematics or science and we have been working with a number of universities to develop training

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Dr Michael Day, Dr Stephen Baker, Dr Derek Bell and Mr Phil Bunyan

programmes for people. We really are working very much on offering opportunities for technicians who want to move into a teaching role and work with young people. We have about 280 people at the moment on a pilot.

*Dr Bell:* We published a leaflet in collaboration with the Royal Society and CLEAPSS based on the reports that we have done on technicians over the year and the work that Phil has just drawn to your attention. It sets out a four stage career structure for technicians. If you look at the back the logo is endorsed by an awful lot of people. We were then very disappointed when the government brought in their workforce agreement and then did not have a category which was specifically for technicians, both science, D & T and other areas, because they were seen as being linked to the teaching assistants. That is the risk that we just talked about. You end up having people who move out of the prep room and into the

lab and therefore there is nobody left in the prep room to do the work that needs to be done there. That is one of the problems. TDA know this because we have spoken to them about it quite consistently. One of the things that we have done to try and address some of the issues is we are working with DATA, the Design and Technology Association, to create an assessment centre for technicians in schools, funded at this moment in time through Gatsby, so that they can get qualifications, NVQs principally, to recognise where they are in terms of their career, so they have some recognition that they can qualify to do certain things and hopefully boost their career structure and their progression.

*Chairman:* Thank you all very much. It has been a very useful session indeed. You know where we are if you think of anything else that we need to know. Thank you very much for coming and spending the time.

### Supplementary evidence by CLEAPSS

1. This additional submission is concerned with the quality and effectiveness of newly built or refurbished science laboratories in schools. There are three points we wish to make:

- The quality and effectiveness of recently rebuilt or refurbished school science laboratories is too often below an acceptable standard.
- Some guidance (PFS Area Data Sheets) produced by the DfES for building new science laboratories appears inadequate and often fails to make reference to, or take account of, the DfES' own guidelines in Building Bulletin 80 *Science Accommodation in Secondary Schools*.
- A new DfES project, *Project Faraday—Re-inventing Science Labs* will guide and support the building of at least three exemplar school science accommodation solutions. We are concerned that it may, in its search for innovation, produce particular solutions which although innovative and appealing at a range of levels may not meet the general needs of practical science teaching in the long term.

2. The data in below (and in appendix 1) are taken from *Improving School Laboratories?*, a draft, as yet unpublished, report by CLEAPSS for the Royal Society of Chemistry and the Royal Society. It suggests that over the period 2000–05 the rate of refurbishment of science labs was around 4.7 per cent per year and the rate of new build around 2.2 per cent. Other findings include:

- 28 per cent of science departments thought the quality of their new or new or newly refurbished labs was unsatisfactory or poor.
- 13 per cent of science staff were unsatisfied with the range of teaching approaches possible in the new or newly refurbished laboratories.
- 39 per cent of science staff were unsatisfied with the ICT facilities in the new or newly refurbished laboratories.
- 33 per cent of science staff had little or no involvement with the design or refurbishment of the science accommodation.

(more details can be found in appendix 1.)

It would seem that much more care is needed by all concerned when planning, commissioning and designing new or refurbished science laboratories if they are to be fit for purpose and sufficiently durable.

3. We have recently had sight of *PFS Area Data Sheets for: science laboratories; enhanced science room; science preparation room; and ICT/data logging science laboratory*, produced by the Partnership for Schools section within the DfES. Although it is not clear the precise status of these documents we understand that copies have been distributed to some local authorities for use with architects. The documents provide guidance on quantity and/or positioning of internal fixtures, fittings and facilities including gas and water supply, tables,



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chairs and storage etc. There is a great deal of commonality between the different documents including commonality of errors and omissions. There are also differences, for example, the document for science laboratories does not refer to the excellent DfES publication Building Bulletin 80 *Science Accommodation in Secondary Schools* whereas the documents for enhanced science room and science preparation room do. Our principal concern is the inconsistency and evident lack of care which has been taken in the production of these documents. Should their use become widespread, then otherwise uninformed local authority officers and architects will, with the best of intentions, plan science facilities which will not be fit for purpose and may in fact be a constraint on effective science teaching.

4. Project Faraday has as its aim “to develop concepts and ideas for new types of science facilities which support more interactive and exciting ways of teaching and learning, with innovative use being made of ICT”. We support wholeheartedly the basic principle although we believe that effective practical work already provides at least one interactive and exciting way of teaching science. The project will also “act as exemplars for science provision in all future building projects” and among the issues to be considered are “alternative or multi-functional learning spaces where science can be taught (lecture theatres, drama studios)” and “the latest technologies from other disciplines (such as museums) brought into schools.” Significant importance is being placed on the outcomes of this project. A book of exemplar designs is to be published by August 2007 and the first demonstration project is to be opened by March 2008. Given the design and build quality weaknesses identified in paragraphs 2 and 3 above, we want to stress the need to avoid “zany” designs, and that before designs are approved and publicised their effectiveness in practice is clearly established. It would be better to encourage architects to implement the sound advice in Building Bulletin 80.

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#### APPENDIX 1

Further selected data from *Improving School Laboratories?*; a draft report for the Royal Society of Chemistry and the Royal Society.

The data are given here in the form of responses to questions:

- A. What was the quality of the building works, furniture and fittings?
- |                |     |
|----------------|-----|
| Very good      | 12% |
| Good           | 61% |
| Unsatisfactory | 23% |
| Poor           | 5%  |
- B. How satisfied are you with the range of teaching and learning styles that the new laboratory makes possible?
- |                  |     |
|------------------|-----|
| Very satisfied   | 24% |
| Satisfied        | 64% |
| Unsatisfied      | 11% |
| Very unsatisfied | 2%  |
- C. How satisfied are you with the level of ICT provision in this/these labs?
- |                  |     |
|------------------|-----|
| Very satisfied   | 20% |
| Satisfied        | 43% |
| Unsatisfied      | 24% |
| Very unsatisfied | 13% |
- D. To what extent were members of staff (teachers &/or technicians) consulted during the design process and subsequent building works?
- |              |     |
|--------------|-----|
| A great deal | 35% |
| Some         | 32% |
| A little     | 25% |
| Not at all   | 8%  |

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In the main, issues of quality were to do with furniture and fittings, particularly cupboard doors and locks which too often “fall to pieces” under normal use. In addition 71 per cent of respondents to the survey reported maintenance problems with their new laboratories. Much of this is likely to be “snagging”, the process of attending to minor faults at the end of any building work. However some faults were more significant and included faulty drainage systems, faults in the gas and water supply as well as cupboards falling apart.

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# Written Evidence

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## Memorandum by the Association of the British Pharmaceutical Industry

### BACKGROUND

The Association for the British Pharmaceutical Industry (ABPI) is the voice of the innovative pharmaceutical and biopharmaceutical industry, working with Government, regulators and other stakeholders to promote a receptive environment for a strong and progressive industry in the UK, one capable of providing the best medicines to patients. Members range in size from multi-national, integrated pharmaceutical companies, down to small growing companies and contract research organisations.

The future productivity of the UK depends on improved practical science and technical skills and improved higher level numeracy—skilled employees are needed from vocational, technical levels, to higher research level. We therefore welcome the House of Lords Science and Technology Committee Inquiry into Science Teaching in Schools.

The pharmaceutical industry in the UK is concerned that insufficient numbers of high quality skilled science graduates with good depth of subject knowledge are currently being educated in UK; indeed many graduates lack basic scientific practical skills. Despite the number of full time undergraduate students having grown by 14% from 1997–98 to 2004–05, in the physical sciences numbers have decreased.<sup>1</sup> Indications are that this trend may be starting to reverse, however efforts must continue to inspire and encourage young people to study physics and chemistry at GCE A level and beyond.

In 2005 ABPI set up a taskforce to research issues around recruitment of employees with the skills the industry demands, into research, development and manufacturing areas. The report of the taskforce's work; *Sustaining the Skills Pipeline in the pharmaceutical and biopharmaceutical sectors* was published in November 2005.<sup>2</sup>

We welcome the support that Government is giving in taking forward many of the recommendations of this report, notably the setting up of a Taskforce to investigate issues around supply of scientists with *in vivo* skills, and encouraging debate on the need for a 14–19 Science Diploma.

### SUMMARY—KEY POINTS

- The pharmaceutical industry in the UK depends on a supply of scientist, engineers and technicians at all levels. The quality of science teaching in schools is crucial to inspire and support young people in their study of science.
- We recognise that the Government is proposing action to address issues in relation to science teaching, the numbers of qualified science and maths teachers, and the supply of scientists, engineers and technologists through its Science and Innovation Investment Framework and we welcome many of these proposals.
- The industry has concerns, particularly over the practical skills of new recruits. We believe that practical science activities must be encouraged and adequately funded at school, and in further and higher education.
- Pharmaceutical companies support science teaching in schools in a number of ways. Specific examples are provided under the appropriate sub-heading.

### *Current situation*

1. Ofsted has shown that there is a high correlation between pupil achievement and science teacher expertise. In 45% of schools with an excellent or very good match of teacher specialism to the curriculum, pupil achievement is excellent or very good, whereas in schools where match of teacher specialism to the curriculum is unsatisfactory this drops to 4%. In this latter group, in only 22% of schools was the teaching rated as good

<sup>1</sup> Higher Education Statistics Agency—Students and qualifiers data tables, Subject of Study. Information available at <http://www.hesa.ac.uk/holisdocs/pubinfo/stud.htm>

<sup>2</sup> Sustaining the Skills Pipeline, ABPI November 2005. <http://www.abpi.org.uk/publications/pdfs/2005-STEM-Ed-Skills-TF-Report.pdf>

by Ofsted; in the schools where the match was excellent/good, 94% of teaching was good or better. It is therefore of great concern that many schools are unable to recruit sufficient physics and chemistry teachers to deliver these subjects to all pupils. Nearly half of all secondary science teachers have a specialism in biology, with only 25% being chemistry specialists and 19% physics<sup>3</sup>. A small percentage of teachers of science have no qualification in the subject or are predominantly teachers of other subjects. Without sufficient numbers of well qualified teachers of all specialisms in all schools, pupils will have fewer opportunities to succeed in science.

2. It is also a concern that the number of teachers leaving teaching before their normal retirement age has increased by a third from 15,700 in 1997–98 and 20,900 in 2003–04 (the latest date for which figures are available from DfES).

#### *Attracting and training new science teachers*

3. Data from the DfES<sup>4</sup> indicates that, although recruitment of secondary school science teachers has increased markedly in recent years, the numbers being recruited are still below the target number for each year and, equally important, the distribution of science specialism in these new teachers is not even. Far fewer physics and chemistry teachers continue to be trained than biology specialists. This concerns us greatly as we believe that an excellent level of subject knowledge is the key factor in equipping teachers to enthuse and stimulate students' interest and enjoyment in science.

4. Equally of concern to us is the retention of excellent teachers in the profession. To date most initiatives have focussed on recruiting new teachers rather than creating additional incentives aimed at retaining talented science teachers. We were pleased, therefore to note that the Science and Investment Framework: Next Steps paper asks the School Teachers' Review Body to advise on improving the use of current pay incentives and flexibilities to improve the recruitment, retention and quality of science and mathematics teachers.

5. Primary schools generally expect the class teacher to teach most, or all, subjects. A recent survey has shown that many teachers feel inadequately trained to cover the science curriculum with confidence.<sup>5</sup> Although children generally enjoy science at this stage, the curriculum content, focus on assessment, together with, in some cases, lack of confidence of the teacher, may lead to restrictions on open-ended practical work and opportunities to make the science topics relevant to children's lives

The AstraZeneca Science Teaching Trust is an independent charity with a significant trust fund.<sup>6</sup> The Trust supports a programme of projects designed to build knowledge and skills in order to support science teachers in primary schools. In addition the Trust sponsors a science education forum that brings together stakeholders in education, industry and Government to build consensus on science education policies and practices.

#### *Teaching science*

##### Professional support for science teachers

6. Opportunities for subject specific continuing professional development (CPD) must be an entitlement for all teachers to develop their subject knowledge, especially in subjects such as science where the speed of new discoveries and new theories rapidly outstrips information in text books and other sources of information. We agree with the Biosciences Federation who note the importance of systematic and career-long continuous professional development for science teachers.<sup>7</sup> Their comment: 'Bioscience education depends on enthusiastic teachers who are up to date and able to engage their students in developing an appreciation of the discipline' applies equally to chemistry and physics in our opinion.

7. We are therefore very concerned to learn that recent research by the Wellcome Trust indicates that although science teachers are keen to update their subject knowledge, satisfaction with subject—updating CPD was low and half of all secondary teachers surveyed had had no subject related CPD in the past five years<sup>8</sup>.

<sup>3</sup> *Mathematics and science teaching in secondary schools: The deployment of teachers and support staff to deliver the curriculum*, DfES, January 2006.

<sup>4</sup> Data from TDA's ITT Trainee numbers census 2000–01 to 2005–06.

<sup>5</sup> *Primary Horizons; Starting out in science*, Wellcome Trust, September 2005.

<sup>6</sup> [www.azteachscience.co.uk](http://www.azteachscience.co.uk)

<sup>7</sup> *Enthusing the next generation*, Biosciences Federation, November 2005.

<sup>8</sup> 'Believers, seekers and sceptics' Wellcome Trust, January 2006.

8. We welcome the opening of the National Science Learning Centre in York and network of regional Science Learning Centres, and we hope that all science teachers will be encouraged and supported by the government, and by their school or college, to attend courses at one of the centres. We hope that subject specific CPD will, in future years be an expectation for all teachers, monitored at their annual appraisal, and will be a major route towards increasing the confidence and expertise of those expected to teach outside their area of specialisation, especially teachers of chemistry, physics, maths and modern languages. One recommendation of the ABPI report is that the Science Learning Centre network, industry and teacher training institutes should work together to develop and support courses to update and extend the practical skills of teachers, and those training to be teachers, and help them update their knowledge of cutting edge research. Courses at Science Learning Centres could become credit based, leading to a certificate which would recognise achievement in subject specific CPD.

9. A particular issue is CPD for teachers of the new science GCSEs, vocational and applied courses including the new 14–19 diplomas. Most science teachers have not had previous experience of industry and need help in delivering the course. The recent introduction of SETNET Regional Directors is intended to ensure that larger numbers of schools benefit from STEM activities. However mechanisms will need to be put in place to ensure that sustainable links between schools and industry are developed that will support these courses in a meaningful way. We have provided an example of how one of our member companies is helping to achieve this in Hounslow (page 132). Science Learning Centres also have a role to play in enabling teachers to recognise the applications of science in industry.

10. We applaud the Government’s recommendation that teachers should be encouraged to join their relevant subject association and suggest that financial support should be made available to encourage this.

AstraZeneca recognises the value of continuous professional development for teachers and the importance of providing sources of information to enrich their teaching and re-engage teachers’ enthusiasm about science. In addition AstraZeneca sponsors summer schools, for example at Manchester University, designed to increase teachers’ confidence, improve scientific knowledge and develop a resource to facilitate the teaching of ethical issues to school children.

GlaxoSmithKline (GSK) and the Science Learning Centre East of England have developed a new course ‘Does A-level Chemistry give you a headache?’ to add an up-to-date, industrial dimension to A level Chemistry teaching. Teachers spend half a day in a specialist science school laboratory synthesising and checking the purity of paracetamol using school-based techniques. They then tour a GSK R&D site and test their samples using industrial techniques. Teachers who take part consistently rate the course Very Good or Good. One commented “It was interesting to see modern techniques which have changed a lot since I was at university”. Over the two years that this programme has been run, 60 participants have attended. Some teachers were accompanied by their technicians to enhance future delivery back at their school.

#### *Effect of changes to the curriculum*

11. The changes to GCSE science courses provide an opportunity for teachers to introduce more discussions, practical work and coverage of topical issues into their lessons than has been possible before due to the heavy content of GCSE science courses. Many teachers will need professional development to increase their confidence to use a different approach and may need additional technical support to increase the practical content of their lessons.

12. The Biosciences Federation report, *Enthusiating the next generation* comments that feedback from a school trialling the new 21st Century Science GCSE noted that teachers found planning and running open discussion session challenging and time consuming. Support should therefore include interaction with teachers of other disciplines to share practice on making social and ethical discussion as stimulating as possible.

#### *Schemes to help generate enthusiasm in young people for science subjects*

13. The industry promotes science as an exciting field with a wide range of career opportunities in a number of ways. Many of these initiatives impact on large numbers of pupils and the wider public.

- Promotion of science in the community through events such as National Science Week, Kent Festival of Science and the Cheltenham Science Festival.

- Support for schools through local SETPOINT activities and the Science Ambassadors Scheme which act at the interface between industry and schools.
- Support by companies for science clubs, prizes for science teaching and student achievement and linking scientists and schools in a variety of ways.
- Visits to research and manufacturing sites and work experience placements.
- Involvement with career related events.

Specific examples include:

The Pfizer Jamboree showcases exciting science activities for children from Pfizer's partner primary schools. In March 2006 the 13th successive Jamboree was held, attracting 2,400 children from more than 60 primary and special schools. Over 150 Pfizer scientists were involved in running activities.

AstraZeneca is one of the main sponsors of the BA CREST Award Scheme. This programme is targeted towards 11-19 year olds and seeks to encourage scientific project work, problem solving and communication skills. Over 20,000 students each year take part in the scheme which enables students of all abilities to explore real scientific, engineering and technological problems for themselves and promotes work-related learning.

Novartis scientists provide support for Chemistry is Fun/Science is Fun events. These evening sessions, funded by the Royal Society of Chemistry, are run for Key Stage 2 pupils and their parents. These are hosted by secondary schools for primary school students. One outcome is to challenge parents' perceptions of chemistry as a difficult, unexciting, subject.

The Virtual Interactive Employer's Workplace (VIEW) is a PC based software application which enables young people (14-16) to access a virtually represented working environment. The resource provides a means to navigate across a 'site' and through panoramic images gather further evidence in the form of close-up images, sequences of images, scanned documents, audio, video and narrative. The evidence provides the young person with access to real material that helps them better understand their chosen subject of study at GCSE level, as well as the application of that knowledge in a real working environment. VIEW at Eli Lilly will primarily support young people 14 to 16 years of age who are studying Applied GCSE Science and will be distributed to secondary schools in the South East of England. The VIEW project has been fully funded through the South East England Development Agency (SEEDA) and supported by six major businesses, including Eli Lilly, in the south-east.

AstraZeneca support Young Engineers clubs, and participate in the Royal Academy of Engineering "BEST" programme in which talented individuals can move through the "BEST" programme from the Engineering Education Scheme and "Headstart" in secondary schools through to the Year in Industry scheme—for A level students who have secured a university place and wish to pursue a year of industrial experience first.

Recruitment of graduate chemists is critical to GlaxoSmithKline's future research. A significant benefit of GSK's Young Scientist Days has been their impact on recruitment into the company. GSK's Young Scientist Days give 190 Year 11 students each year a chance to spend a day with scientists in the company's laboratories working to develop new medicines and a number are then motivated to take part in our Year 12 work experience programme. In this scheme students spend their February half-term holiday in a scientific team in a laboratory. GSK supervisors nominate exceptional students for the Nuffield Bursary scheme. About 20% of the students go on to carry out six week Nuffield Bursary projects in the summer holiday undertaking in-depth pieces of scientific work. Of the ten new graduate chemists employed by GSK's R&D sites in Essex and Hertfordshire in 2004, four had undertaken work experience at GSK, and two had done Nuffield projects.

Pfizer annually host a Biology Project Week. The Year 12 students come from all over Kent and have been selected for their commitment to biology. The seven day, residential course, run at Canterbury Christ Church University is designed to give them an insight into the process of scientific research and potential career opportunities within biology and the life sciences.

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*The role of the practical in teaching science*

14. Our recent report, *Sustaining the Skills Pipeline* identifies low levels of practical skills, and opportunities for development of those skills, especially in areas such as dissection of animals and animal tissues, as a particular issue. Practical skills are essential for practising scientists, and research carried out amongst ABPI member companies clearly indicated deterioration in these capabilities in new employees in the UK compared to those recruited from other countries. We believe that this decline in practical capability of students stems from an overloaded school curriculum, and teachers who do not feel sufficiently confident to allow students to carry out experiments outside their speciality which involve any degree of risk. We hope that the subject enhancement courses being run by the Training and Development Agency for Schools (TDA) to enhance and extend subject knowledge for trainee teachers in chemistry and physics will go some way towards addressing this issue for new teachers; however the needs of practising teachers must also be addressed.

15. New graduate teachers, even those teaching within their area of specialisation, are likely to have had fewer opportunities to experience practical science themselves at school and university and are therefore less confident and less likely to provide the right practical experience. The cost of supporting practical work in Higher Education, leading to reduced laboratory time for students, is an important factor, with many students no longer carrying out a substantial practical project as part of their degree. We do not feel that sufficient efforts are being made to address this funding issue through an urgent review of the funding for teaching provided by the Higher education Funding Council for England.

*Schools*

## Variations between schools in the teaching of science

16. We are aware that there are significant differences in achievement between students of similar ability who experience different types of science education; however we are concerned that Government policy appears to be based on evidence that is not universally agreed and that major new initiatives appear to be preferred over continuing support for successful projects.

17. Evidence presented by DfES, at a seminar held at the Royal Society in June 2006, indicated that opportunities to succeed depend, not only on the type of school attended, but on the area of the country where the student lives. We are not convinced, however, that the measures proposed by the Government in the paper *Science and Innovation Investment framework: Next Steps* will be successful. We are concerned that there is a risk that science may become a subject that is considered as a career only for the most able and that routes towards vocational working in science are not being adequately supported by Government.

18. Whilst there are excellent examples of science outreach and partnership activities by specialist science schools, in some cases specialist science schools appear to be taking a “tick box” approach, taking the action necessary to meet the set criteria, rather than embracing the philosophy underpinning the role of the specialist school. In addition, in many cases there are existing mechanisms to support science teaching in schools within local authorities, such as Heads of Science meetings and continuous professional development for teachers. As a result, science specialist schools can find it hard to find a role in supporting other secondary schools with advice on science teaching.

*The condition of school laboratories*

19. A number of recent reports have highlighted concerns with the state of school science laboratories and the effect that an old, uninspiring laboratory might have on encouraging an interest in science.<sup>9</sup> Although money has been pledged by the government to upgrade and re-equip older laboratories, this does not appear to have been delivered to schools, and certainly hasn't resulted in the expected impact.

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<sup>9</sup> *Laboratories, Resources and Budgets; A Report for the Royal Society of Chemistry on Provision for Science in Secondary Schools*. Information available at: [www.rsc.org/pdf/education/labreports2004.pdf](http://www.rsc.org/pdf/education/labreports2004.pdf).  
*The Annual Report of Her Majesty's Chief Inspector of Schools 2004/5—Science In Secondary Schools*. Information available at <http://www.ofsted.gov.uk/publications/annualreport0405/4.2.15.html>

*Links between schools, universities and industry to facilitate science teaching*

20. Pharmaceutical companies, and the ABPI, support science teaching at all stages of the education system, from primary and secondary education through to further and higher education. This includes providing a range of initiatives and resources that support and promote teaching and learning of science.

ABPI provides a range of interactive web based resources to support science teaching from primary school to sixth form<sup>10</sup>. The resources link science in the curriculum to the way in which it is used in industry, with links to diseases and their treatment. Additionally resources investigate the pharmaceutical industry as a business, the process of manufacturing medicines and the history of medical treatments.

AstraZeneca have developed a number of teaching resources including web based activities and a number of aids including lung and cancer toolkits for teachers, designed to increase knowledge and understanding of these important areas of science.

Merck Sharp & Dohme use a hands-on business game to students experience in, and the ability to appreciate, aspects of a manufacturing company. The aim of the game is to manufacture widgets for a customer, always meeting the customer's delivery demands, using a fixed assembly sequence with the target of making a profit of £2,000+ at the end of the game. The Game proved an effective tool in teaching the students the importance of communicating with people and how talking to people can help avert issues, how quality should be built into everything that we do and how training underpins much of what we do in life.

Through the GlaxoSmithKline sponsored INSPIRE (Innovative Scheme for Post-docs in Research and Education) post-doctoral researchers (post-docs) from Imperial College spend half their time studying for a Post-Graduate Certificate in Education (PGCE), assisting with science teaching and enrichment activities in specialist schools sponsored by GSK. The remainder of their time is spent undertaking scientific research. An interim evaluation indicated that schools believe that the post-docs presence and activities are having a positive effect on student interest, uptake of science courses post 16 and applications for science related courses in higher education. Activities organised by the post-docs include running after school science clubs and CREST Awards, taking students on visits to Imperial to experience life as an undergraduate, and to use equipment at Imperial to carry out science investigations, running A level masterclasses, and acting as positive role models for students. It is planned to extend the scheme to other UK higher education institutions and schools.

Three schools, a further education college and four employers in the London Borough of Hounslow (including GlaxoSmithKline) are working in partnership to support teaching of the new science GCSE specifications to be introduced in September 2006 and a BTEC First Applied Science diploma course. The project is managed by Hounslow Education Business Partnership and funded by the Learning & Skills Network (LSN).

The following outcomes are anticipated:

- work-related assignments and teaching materials to support units of work will be produced by the schools and employers. It is expected that these will be used with successive cohorts of GCSE students on a sustained, rather than a one-off basis;
- the employers will visit the schools to support teaching of the units of work;
- students will be enabled to build, explore and apply their understanding of science;
- dissemination of project outcomes, including assignments and materials, to other Hounslow schools in 2006;
- extension of project to other Hounslow schools and employers in 2006–07.

Key factors in the success of the project have been the brokering and project management role provided by Hounslow EBP, and the time invested in in-depth discussions between the teachers and employers to enable the schools to understand what the employers could offer, and for the employers to understand the schools' needs.

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<sup>10</sup> *Resources for Schools* www.abpischools.org.uk



### Memorandum by Dr John Baruch

#### INCREASING ACHIEVEMENT IN STEM SUBJECTS—OVERVIEW OF THE BRADFORD ROBOTIC TELESCOPE

1. The objective of this note is to present evidence of the unique role played by the Bradford Robotic Telescope (BRT) in developing a new approach to laboratory work which is low cost and freely available to all teachers and their pupils. It is particularly concerned to support non specialist teachers teaching science and specialist teachers teaching science outside their specialism.
2. The BRT currently has a Nuffield Foundation funded programme to introduce the project to schools through the initial teacher training programmes.
3. A brief Scottish evaluation and comments are attached. A further evaluation of the BRT funded by the Yorkshire RDA (Yorkshire Forward) will be presented at an event sponsored by Barry Sheerman and Phil Willis in the Strangers Dining room in the House of Commons on 6 July 2006 from 4 pm to 6 pm. A copy will be sent to the Committee as soon as it is available.

#### SUMMARY

4. The Bradford Robotic Telescope offers a new type of e-laboratory to build on the success of Primary science. It aims to link in with the positive experiences in KS2 to provide motivation in KS3 and KS4.
5. The Bradford Robotic Telescope offers a unique low cost route to raising achievement in Secondary Science. It provides extensive classroom support for teachers. It supports independent learners and personalised learning providing a differentiated learning structure which enables students to work at their own pace at school and at home. It has been reported to be highly motivational for both teachers and pupils.

#### SUPPORTING ACHIEVEMENT IN STEM SUBJECTS

6. The World Wide Web made possible a vision of the world as a classroom providing inspirational learning. The Bradford Robotic Telescope (BRT) team, with their partners, have delivered the vision for a part of the science syllabus of the English and Welsh National Curriculum and believe that they can extend their technology to deliver inspirational personalised learning for most of the STEM part of the National Curriculum.
7. The Bradford team have worked in partnership with the Sheffield Hallam Science Centre, Bradford College Department of Education, the Nuffield Foundation, the Institute of Physics, the ASE, the OU and others to develop the telescope system, ([www.telescope.org/](http://www.telescope.org/)) for primary and secondary science teaching in schools. They have also run small pilot projects with Shell and the Drax power station to extend the idea of an e-STEM (Science Technology Engineering and Maths) laboratory beyond astronomy into other areas of the science National Curriculum.
8. The Bradford Robotic Telescope has become an extensive e-teaching and learning web site focussed on the Earth and Beyond sections of the National Curriculum and supported by a robotic telescope. In this role it has demonstrated that it is a facility that is inspirational in the classroom for teachers and learners and can support the learning programmes of all students in the UK. This experience led to the generic idea of an e-STEM laboratory.
9. An e-STEM laboratory is a new type of learning web site supported by a real world facility which provides real time access to operational data to support learning programmes. The learner has a degree of freedom to define which data which they wish to obtain from the facility and to generate information in support of their learning programme.
10. The pilot e-STEM laboratory project is using the BRT to support part of the English and Welsh KS2, 3 and 4 science curriculum. It appears to be a significant success for students and teachers and can deliver this service to all students in the UK as the students progress through the National Curriculum.
11. The core of this BRT *effect* appears to be that it takes the students into the world outside the classroom where they can request their own data from real world facilities to support their own learning programmes. When the data is delivered to them they process it themselves to extract their learning. This process more closely reflects their developing understanding of the world, where extensive input from the Internet and television now supplements the views of teachers and parents.

12. It is argued that the BRT delivers a new form of practical experience supporting teaching and learning and complementing traditional laboratory experiences. It is maintained that this technology can be extended across the science syllabus and into other areas. We see the development of two or three e-STEM laboratories as national resources providing an effective route to help achieve the increase in progression into qualifications and careers in STEM subjects described in the *10 year science and innovation investment framework 2004–2014*, recently updated (March 2006) by HMT, DfES, DTI and DoH.

#### HISTORY

13. The BRT was originally funded by PPARC as a technology prover instrument for astronomy. It started life operating in the UK and was overwhelmed with observing requests from school students and their teachers. Educational programmes were funded by the Nuffield Foundation, and PPARC with technical developments funded by the Royal Society and the Nuffield Foundation. The telescope was moved to a world class observatory site in the Canary Islands and operated in collaboration with the Instituto de Astrofísica de Canarias.

#### ACCESS FOR ALL

14. The BRT is reached through its web site (<http://www.telescope.org/>). It is focussed on space and astronomy access for all. Unlike any of the other 200 or so robotic telescopes in the world the BRT with its educational web site concentrates on the fundamental levels of astronomy eg why we have days and nights, why seasons and why the Australians don't fall off. The objective is to deliver images of the heavens to support understanding of the basic ideas that underpin our modern views of the Earth and its place in the Cosmos. Unlike any of the other robotic telescopes, the BRT is free and requires no previous knowledge. If you want an image of the stars eg to support your studies, you can go e-shopping and select from the night sky the images that you need. In a world that lives behind the haze of light found in modern urban living, the aim is to deliver the awe and majesty of the night sky to citizens, students, teachers and parents.

#### THE BRADFORD ROBOTIC TELESCOPE IS A UNIQUE EDUCATIONAL RESOURCE

15. The BRT is a unique educational resource:

- (a) It can support all school students following their national curriculum studies.
- (b) It delivers science through interactions with the real world outside the classroom.
- (c) It delivers personalized responses for each student and can be used from home.
- (d) It first inspires pupils at key stage 2 aged 9 to 11 and then re-engages with them at key stages 3 and 4 aged 12 to 16.

16. The Faulkes and Liverpool telescopes are research instruments which only image a tiny area of the sky; a fraction the size of the Moon. Unlike the Faulkes and Liverpool robotic telescopes that are available to UK school children the BRT is primarily for under 16 education programmes with images that include whole star constellations visible to the naked eye as well as distant galaxies. Although it also has research programmes, it is focussed on the education task and can deliver astronomy laboratory experiences to all the UK school students. The Faulkes and Liverpool telescopes complement the BRT providing an excellent resource for a limited number of post 16 education groups and astronomy clubs.

17. The BRT system currently (May 2006) has over 7,000 registered users and has returned over 13,000 observing requests. It is undergoing an evaluation funded by Yorkshire Forward (the Yorkshire RDA) and an evaluation from Glasgow University (Anne Campbell 2006) is attached as an appendix, which examines its appropriateness for Scottish school children. The evaluation by Yorkshire Forward is expected by the end of June.

18. It might seem strange that the Bradford Robotic Telescope (BRT) can support all children in the UK whereas the other robotic telescopes can only support a couple of thousand users. There are two components that make this possible.

- (a) The BRT is uniquely a service robot. Virtually all other robot telescopes are allocated to users in short time slots 10, 30 or 60 minutes and the user or group of users actually drives the telescope around the sky. The BRT schedules its observations when the weather conditions are appropriate and returns the image to the user. The user does not need to learn how to drive a telescope and most observations can be taken in little more than the exposure time which is a fraction of a second for bright objects and a minute for normal star fields.

- (b) Experience has shown us that there is only one in 10,000 requests that is outside a list of about 25 objects that school students have heard of. All these 25 objects can be imaged in 30 minutes three or four times per night.
- (c) Images are allocated to the user to process as s/he requires and it has been found that it does not detract from the excitement of the experience that the whole class has the same image eg of the moon. It is returned as the personalised image of each pupil and each pupil processes it differently.

**BRADFORD ROBOTIC TELESCOPE [www.telescope.org](http://www.telescope.org): THE FIRST E-STEM LABORATORY**

19. To empower teachers in the classroom with:

- (1) Easy to use: the telescope requires little or no astronomical experience.
- (2) No need to install any software, all you need is internet access.
- (3) Students access the real world in a programme of enquiry based learning.
- (4) Full range of educational pages with animations, games and simulations backed by online summative and formative testing with student and teacher feedback.
- (5) Focussed on the UK National Curriculum sections “the Earth and Beyond”. All appropriate syllabus needs in one location for students aged 10 to 16.
- (6) Teacher’s notes: ideal for non specialist science teachers and first time teachers with clear minute by minute lesson guides, keywords and example work.
- (7) Full range of Student handouts available online to support activities.
- (8) Differentiated learning and accessibility support through intelligent adaptation to the multiple learning styles of students.
- (9) Designed for every user to take their own astronomical images.
- (10) Free access for all anywhere any time.
- (11) Tenerife based telescopes: one of the best observatory sites in the world.
- (12) Designed and tested to support millions of users.

20. The telescope is cocooned in sets of weather sensors, environmental sensors and webcams most of which are directly accessible and archived. At the centre of the system sit three telescopes: the first for wide angle (40 degree) constellation images, the second for three degree wide images which cover the full moon and star clusters, and the third for half degree wide images providing detailed images of the Moon, the planets, galaxies and nebulas. Access to this real world tool is at the centre of our enquiry based learning ethos, with first hand data we hope to get users involved with a topic that might otherwise have felt as distant as the stars themselves. It is an experience that many students enjoy and positive feedback from trials shows that as many as 10% of students continue to use the telescope in their own time long after the classroom sessions have finished. In this way it is hoped to immerse students in family learning and develop a culture of life-long learning.

**CONCLUSIONS**

21. The BRT has demonstrated the effectiveness of an e-STEM laboratory to inspire young people with the STEM subject areas.

**REFERENCES:**

- 22. The Bradford Robotic Telescope: Its relevance to the Scottish schools’ curriculum. Anne Campbell May 2006. Available from John Baruch University of Bradford, Bradford BD7 1DP and John Brown, Astronomer Royal for Scotland, Department of Astronomy, University of Glasgow. Glasgow G12-8QQ.
- 23. The Hoshin Report on the Bradford Robotic Telescope for Yorkshire Forward will be published by the end of June and is being presented at the House of Commons 6 July at 4 pm in the Strangers Dining Room.

*4 June 2006*

### **Memorandum by the British Association for the Advancement of Science**

The BA welcomes the opportunity to respond to these proposals, and in particular to address two of the Committee's stated issues:

- The impact of existing schemes designed to help generate enthusiasm in young people for science subjects.
- The role of the practical in teaching science.

The BA believes passionately in the value of a science education that gives all students the opportunity to:

- develop the scientific literacy that they need to play a full part in a modern democratic society, in which science and technology play a key role in shaping our lives, as active and informed citizens; and
- undertake the first stages of their training as a scientist, or for a career that involves science, should they be attracted to that vocation.

The science curriculum should therefore offer young people:

- an understanding of the major scientific explanations that enable us to make sense of the natural world around us and to make reliable predictions; and
- the ability to reflect on scientific knowledge itself, including the practices that produce sound knowledge (as well its provisionality and continued openness to challenge and testing), the kinds of reasoning that are used in developing a scientific argument, and the issues that arise when scientific knowledge is put to practical use.

#### **THE IMPACT OF EXISTING SCHEMES DESIGNED TO HELP GENERATE ENTHUSIASM IN YOUNG PEOPLE FOR SCIENCE SUBJECTS**

The BA runs the BA CREST Awards, the UK's national scheme for supporting and accrediting student-led project work in science and technology. An extensive evaluation of this scheme is close to completion, carried out by Liverpool University and funded by AstraZeneca.

Initial findings indicate that the scheme has a strong positive impact on students' attitudes towards SET generally and SET careers, and it appears that students gain knowledge and a number of transferable skills from their participation.

In general, assessment of impact is a perennial challenge in this field. Quite apart from the difficulty of isolating the impact of one intervention within the complexity of other factors, it also reflects different priorities and objectives for organisations seeking to intervene. These may legitimately vary from generating enthusiasm per se to encouraging a more positive attitude to science and technology, increasing uptake of science subjects at various levels, developing skills, attracting people into science-based employment and improving examination attainment levels. The Tavistock Institute has recently been commissioned by the Economic and Social Research Council, stimulated by the Office of Science and Innovation, to assess methodologies for evaluating the impact of public engagement activities, and we await the findings with interest.

We do notice a greater willingness now, compared with 5–10 years ago, for organisations committed to science curriculum enrichment and out of school activities to work more closely with each other. Whereas government can, and should, do more to co-ordinate its own schemes for support (within the DfES and between the DfES, DTI and other departments), expecting managed "co-ordination" of so many independent schemes from commercial and not-for-profit organisations, each with their own objectives, is likely to be unrealistic. We would rather recommend the concept of "intelligent networking", with government looking to support and highlight organisations and initiatives that offer this, and to support teachers and schools (who will ultimately make judgements of value and quality) to act as well-informed customers.

In this respect, the BA has repeatedly stated and demonstrated its commitment to working with SETNET and the SETPOINTS in the schools sector rather than establishing separate and potentially competing activities. The BA CREST Awards are increasingly used by individual schemes (such as the Engineering Education Scheme or Nuffield Science Bursaries) to provide informal accreditation of student achievements to a common standard, and we are working actively to extend this.

## THE ROLE OF THE PRACTICAL IN TEACHING SCIENCE

The BA is particularly concerned that people should experience science and technology through engaging in exploratory and open-ended scientific and technological activities themselves. That is why the BA runs the BA CREST Awards, the UK's national scheme for supporting and accrediting student-led project work in science and technology, in close partnership with SETNET and the SETPOINTS, and why it hosts ECSITE-UK, the science and discovery centre network.

Project work allows students to gain experience of some of the technical skills associated with doing science as well as benefiting from team working and problem solving. Enrichment activity such as the BA CREST awards allows students time to do the activities which are often squeezed out of normal curriculum time.

In this respect we welcome the announcement in the "Science and innovation investment framework 2004–2014: Next Steps" document of a pilot of 250 after-school science clubs, given our considerable experience of supporting such activities over many years, and look forward to working with the DfES and other partners to help make this a reality.

*June 2006*

### **Memorandum by the British Ecological Society**

#### INTRODUCTION

1. The British Ecological Society, founded in 1913, is the UK's learned society for ecology. The Society's primary objective is to promote ecology worldwide.
2. The BES's involvement in science teaching in schools is through supporting fieldwork and promoting good practice among teachers at all academic levels. The BES supports work in this area by offering a number of funding opportunities to enable the education of young ecologists. The BES is helping science teachers develop their expertise in fieldwork through sponsoring training courses specially designed for trainee, newly qualified and practicing science teachers in collaboration with the Field Studies Council. The BES Education Officer provides advice to teachers about ecological fieldwork on a one-to-one basis and is involved in delivering in-service training (INSET) to teachers focusing on the effective use of school grounds to enhance science teaching. The BES website ([www.britishecologicalsociety.org/education](http://www.britishecologicalsociety.org/education)) provides information and resources for teachers. The BES also maintains the website [www.fieldworklib.org](http://www.fieldworklib.org), the site for professional fieldwork and outdoor science activities.
3. The BES believes that the profile, role and importance of the practical education, in particular fieldwork, in science lessons need to be improved in schools. The BES is doing its most to support fieldwork in schools, but would like to see the Government do more in this area. This response focuses on fieldwork in science teaching in schools.

#### PRACTICAL SCIENCE IN SCIENCE TEACHING

4. Practical work enables students to develop their scientific skills by using equipment, conducting their own investigations and communicating with classmates. These are both essential science and more general life skills. Therefore, the BES believes that science education needs to be bolstered through real world learning.
5. Pupils recognise the importance of practical work in allowing them to understand the topic they are studying in context. Of 150 students involved in a recent fieldwork project (British Ecological Society and Field Studies Council), every student involved recommended that fieldwork continue to be developed in their schools.
6. The Education and Skills Select Committee also recognised the importance of fieldwork in its report "Education Outside the classroom". The Department for Education and Skills responded by creating the "Education Outside the Classroom Manifesto". The BES supports the general aim of the Manifesto, but would like to see science education specifically supported by the DfES through its Manifesto commitments. Urgent changes are needed to policies and the level of resources available to enable students to have meaningful fieldwork experiences.

*Teacher training*

7. Teacher training is increasingly limited to covering the content of the various schemes of work and examination specifications that schools are likely to implement. The result is too little time spent on preparing new teachers for the demands of delivering practical lessons.

8. It has been reported by heads of department in schools that new teachers are lacking the skills and confidence to deliver practical lessons. The BES is greatly concerned with the lack of opportunities in the majority of teacher training courses to develop fieldwork skills. A coherent policy for fieldwork science education would benefit teacher trainers in higher education to safeguard their budgets and encourage trainee teachers to develop this component of their skills base.

*Science Learning Centres*

9. Science Learning Centres have developed a range of courses to provide professional development for science teachers. However, of six science departments recently approached in a joint British Ecological Society and Field Studies Council Project, three did not know what the Science Learning Centres were or their role in the professional development of teachers. This is unfortunate as Science Learning Centres are cancelling courses due to lack of uptake. While the number of schools approached is small, the anecdotal evidence suggests that much more effort needs to be placed on marketing this resource to teachers in schools.

10. Schools that were aware of the Science Learning Centres rarely attended courses due to the overall cost of the courses combined with supply costs. The British Ecological Society partially or fully fund some Science Learning Centre courses but this only accounts for a small number of teachers each year and is subject specific. The success of the Science Learning Centres appears to be largely dependant on funding from organisations, like the BES, for the foreseeable future if other solutions cannot be found. Such a system is likely to generate a bias in the provision of professional development.

*Enthusiasing students*

11. Fieldwork should be seen as an essential part of science education, because it actively engages students in science. Fieldwork provides a real world context whether the topic studied is biology and food chains or physics and gravity. This helps enthuse students about science.

12. The BES is concerned that some pupils progressing to Post-16 education are receiving a science education that is lacking either completely or partially in practical work. This can result in some candidates failing to complete courses through a lack of interest and enthusiasm. In some instances, able students will opt for vocational courses where emphasis is placed on more practical and independent learning systems. The BES feels that any recommendations to improve A-level entries will need to place a strong focus on practical work as an integral experience to the course.

*Links between University and Schools*

13. A successful example of good links between universities and schools are annual field trips developed by trainee teachers and attended by Year 9 students. This provides excellent opportunities for trainees to develop their fieldwork skills, in-school teachers to observe the delivery and students to experience the real world. Such courses involve all trainee science teachers and therefore encourage development non-subject specific knowledge. However, these programmes are under threat from budget cuts. The British Ecological Society would like to see the promotion of such programmes across all teacher training facilities.

14. Researchers in residence provide excellent opportunities for the delivery of up to date science but they are often restricted to Post-16 classes and often the above average schools. Such opportunities benefit both schools and researchers and should be implemented more widely.

*June 2006*

### **Memorandum by the British Psychological Society**

#### **EXECUTIVE SUMMARY**

- Psychology has been re-classified as a science and we request that it be included in the inquiry alongside physics, chemistry, biology and mathematics.

- Psychology is the fastest growing science subject, attracting many people to science who may not have otherwise studied a scientific discipline.
- Psychology attracts a large proportion of women to science.
- Psychology is frequently taught by non-psychologists and often non-scientists.
- Lack of funding for psychology strains in PGCE makes it difficult for psychology graduates to get on teacher training courses.
- Those psychology graduates who are teachers, find it difficult to gain QTS as psychology is not taught across two key-stages.
- Due to psychology often not being classed as a science in the traditional sense, the resources required to support the scientific method that underpins the discipline are often not supplied or are inadequate.

1. The British Psychological Society welcomes the opportunity to provide evidence to the House of Lords Science and Technology Select Committee. This response has been prepared by the Society's Psychology Education Board and the Standing Committee on Pre-Tertiary Education. The Board comprises representatives from a wide variety of backgrounds of psychological education, including academics, A Level examination boards and representatives from the Further Education Sector, as well as a cross section of representation from other areas of our Society.

2. Psychology is the fastest growing science subject. It not only has a very strong scientific basis in the biological and computational sciences, but shares many similarities with other long established quantitative social sciences. Its diversity is one of its core strengths and as such it has much to contribute to the future development and strengthening of the UK research and science base. According to figures released by the Joint Council for Qualifications (JCQ), over 50,000 students sat the Psychology A level in 2005, significantly more than in Physics (28,119), Chemistry (38,851) and rivalling Biology (53,968) and Mathematics (52,879). Psychology also attracts a significant number of women to science, as demonstrated by the same figures from the JCQ which show that 37,237 women sat the Psychology A Level in 2005, with the numbers for Physics (6,197), Chemistry (19,180), Biology (31,922) and Mathematics (20,178) being in some cases significantly proportionally lower.

3. The Qualification Curriculum Authority (QCA) and the JCQ have recently re-classified psychology as a science. Psychology should, therefore, be considered in the inquiry. Although Psychology is not specifically mentioned as being included in the Select Committee inquiry, The British Psychological Society requests that the teaching of psychology in schools be considered alongside the other science subjects. We feel that this is vital given the large number of students undertaking psychology qualifications at school and the importance of the discipline in attracting people into science, especially those who may otherwise not have studied another science subject, thus bucking the trend of decline in other disciplines.

#### *The current situation*

4. It is difficult to gain reliable data pertaining to the number of teachers in psychology. Our Society, in conjunction with the Association of Teachers of Psychology, is currently working on a project to obtain firm statistical data to assess the position. However, it is clear from anecdotal evidence both that psychology graduates find it difficult to gain Qualified Teacher Status (QTS) and also that many people teaching psychology in schools are from other science subjects teaching outside of their discipline or, more seriously, from non-science disciplines. This presents various problems for the students and the teachers, mainly in the analysis of statistics, ethical issues and the research project elements of A Levels.

#### *Attracting science teachers*

5. It seems that psychology does not have a problem attracting psychology graduates who wish to embark upon a career in teaching. However, our Society frequently receives enquiries from students asking for advice because they cannot get on teacher training courses or find it difficult to gain QTS. The main problem appears to be the requirement of the Training and Development Agency for Schools (TDA) that subjects be taught across two key stages, clearly an issue for psychologists, whose subject is only taught at A Level in most schools. Few institutions run PGCEs with a psychology specialism and those that do request that students provide evidence and undertake teacher training in another subject alongside their psychology. It is therefore more difficult for psychology graduates to gain entry onto PGCE courses and the requirement to teach another discipline can be off-putting. This situation is exacerbated by the TDA not providing funding for psychology strands in PGCEs.

6. Measures need to be taken to ease the route to QTS for psychology graduates. The explosion of the subject at A Level has meant that students are frequently taught by non-specialists and while our Society is taking steps to provide support and training for those teaching psychology who do not have a psychological background, there is currently little provision for those teachers, while psychological specialists feel marginalised and under-valued as many of them work without the benefits of QTS. This will become increasingly evident should the moves towards the inclusion of psychology in the national curriculum as a science and the increasing development of a 'knowledge-based economy' rather than a traditional industrial economy continue. The scientific base of the UK is becoming more dependent on new sciences, such as psychology, and this needs to be recognized and adequately resourced.

#### *Schools*

7. The reluctance to accept psychology as a bona fide scientific discipline has meant that lab space and resources are rarely provided to A level that would ensure effective teaching. Scientific method should underpin all psychological teaching.

8. The British Psychological Society thanks the Select Committee for this opportunity to present evidence relating to the teaching of psychology in schools and we hope that our comments will be considered in your inquiry.

*June 2006*

### **Memorandum by the Campaign for Science and Engineering in the UK**

#### **THE IMPORTANCE OF SUBJECT SPECIALISTS IN SCIENCE TEACHING**

1. The Campaign for Science & Engineering is pleased to submit this response to this inquiry into science teaching in schools. CaSE is a voluntary organisation campaigning for the health of science and technology throughout UK society, and is supported by over 1,500 individual members, and some 70 institutional members, including universities, learned societies, venture capitalists, financiers, industrial companies and publishers. The views of the membership are represented by an elected Executive Committee.

#### **THE CURRENT SITUATION**

2. The relatively low number of specialist science teachers in the UK education system remains the single most important factor in need of improvement. Although the total number of acceptances into science teacher training has grown in recent years, the picture is not universally healthy. For example, between 2002 and 2004 (the latest year for which full figures are available), the number of people accepted to train as biology teachers fell by 3% (Note 1). Moreover, the existing shortage will not be rapidly filled by modest increases in supply.

3. The worst situation is clearly in the physical sciences and mathematics. In mathematics alone, the country is short of about 3,400 teachers, which means that even if 40% of all British mathematics graduates were to become teachers for each of the next few years, there would still be barely enough to provide a good mathematical education for all pupils (Note 2). In physics, about a quarter of all state secondary schools do not have any physics specialists (Note 3).

4. Partly as a result of this shortage, a high proportion of teachers are required to teach outside their specialisms. Two-thirds of those who teach physics to 15- and 16-year olds do not have a degree in physics, and one third do not even have the equivalent on an A-level (Note 4). One in 10 of the people who teach chemistry to students between the ages of 11 and 18 do not have any qualification in chemistry. Nine per cent of biology teachers have no biology qualification (Note 5). Only 64% of secondary school lessons in general or combined science are taught by people who claim to have a degree in the subject. 74% of biology lessons, 78% of chemistry lessons and 72% of physics lessons are supposedly taught by people with a relevant degree, but these figures include teachers with general science degrees, not just subject specialists (Note 6).

5. The Government's recent commitment that all pupils who attain the Level 6 at Key Stage 3 will be entitled to study three separate science subjects at GCSE level (Note 7) is admirable in principle, but will be difficult to deliver in practice if the shortage of specialists is not reversed.

6. Data on the retention level of teachers do not appear to be easily available, certainly not broken down by subject. But anecdotal and regional studies paint a picture of a continuing problem. For example, in Northern Ireland, the Department for Education was reported earlier this year as saying that 70% of teachers were retiring early and that this figure had increased rapidly from previous years (Note 8).



### ATTRACTING SCIENCE TEACHERS

7. While existing incentives are welcome, they clearly do not address the underlying perception among many graduates that teaching is an unattractive career, especially in the sciences where unemployment is low and skills are highly valued elsewhere.
8. If the Government is serious about attracting into teaching the numbers of physics and chemistry graduates needed to fill the current shortage, it will need to take account of the market for these people. A recent study showed that people who have a degree in these subjects have a very substantially increased average earning power (Note 9), and with other factors (such as the esteem in which teachers are held) apparently less conducive than in the past to attracting graduates into the profession, more will need to be done.
9. Strong research evidence links earnings potential with decisions about a career in teaching (Note 10). To compete for good quality graduates, the teaching profession will ultimately need more than the relative modest “Golden Hellos” currently on offer.

### TEACHING SCIENCE

10. In our consultations with teachers, CaSE has heard strong criticism of the lack of professional development based around subject content. Science moves forward quickly, and teachers need to feel engaged with developments in their fields. At the moment, most existing professional support appears to be about generic teaching issues (which may be important in themselves), but not to address the more specialized needs of science teachers.
11. Primary school teachers have reported to CaSE that they would appreciate the support of peripatetic science specialists coming into their schools. Most primary school teachers are not trained as scientists and lack the confidence to teach science. Indeed, several secondary school teachers have reported to CaSE that they have had to unpick misunderstandings given to children in primary science lessons. Since a good grounding at the primary schools stage could be hugely important to children, more support for their teachers (perhaps along the lines of the literacy and numeracy strategies) could prove useful.
12. In CaSE’s opinion, changes to the curriculum are not crucial in regard to the recruitment of teachers. Good teachers will make any curriculum inspiring, poor ones will make any curriculum dull.
13. Practical classes are essential in teaching science, which is an inherently practical subject. When CaSE surveyed secondary schools in England (Note 11) and in Scotland (Note 12), we found that large percentages were cancelling practical classes for a variety of reasons, the principal two being a lack of equipment, and concerns about the behaviour of individual pupils. Not a single teacher downplayed the importance of practical work; all the interaction CaSE has had with science teachers, with universities and with employers suggests that practical work is considered crucial by all interested parties, and that all sectors are worried at the decline in practical experimentation and field work in school science courses.

### SCHOOLS

14. One of the most important and under-addressed issues is the insufficient availability of schools laboratory technicians. During a recent meeting in Northern Ireland, for example, teachers told CaSE that it was almost impossible to find trained technicians. In one school a vacant technician’s post had eventually been filled by a dinner lady because no suitably qualified person was available.
15. Some schools laboratories have clearly improved in recent years, but there remains a great deal to be done, and last year the Science Minister, Lord Sainsbury described some laboratories as “appallingly out of date”. However, an apparent promise during the General Election campaign to provide an extra £750,000 per school for improving laboratories has recently been abandoned (Note 13).
16. More generally, a good quantitative study is needed of the ability of schools to excel in science teaching. Some schools have seen an increase in the uptake of science subjects over the past few years, against national trends. It would be useful to know what factors within schools might have affected this pattern. It remains unclear whether status as a specialist science school is important or whether the success of these institutions merely correlates with the fact that they have more appropriate levels of funding to provide facilities.
17. Links between schools, universities and industry could usefully take the form of exchange secondments, whereby teachers could take a sabbatical in a laboratory and those working in active science could come into schools for a while (especially graduate students who may want to give teaching a try). This is exactly the sort of subject-specific professional development that would benefit science teachers and which many have told

CaSE they would welcome. However, funding does not exist to provide cover for staff who are away from the classroom, and there is in any case such a shortage of science teachers that even if funds were available, it is not clear that, at present, high-quality cover could be guaranteed.

#### NOTES

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10. Recruiting and Retaining Teachers in the UK: An Analysis of Graduate Occupation Choice from the 1960s to the 1990s by Arnaud Chevalier, Peter Dolton and Steven McIntosh presented at the Royal Economic Society's 2003 Annual Conference at the University of Warwick, 2003.
11. Survey of Secondary School Science Teachers, CaSE, 2004.
12. Survey of Scottish Secondary School Science, CaSE, 2004.
13. Reported in the Times Educational Supplement, 10 March 2006.

June 2006

### **Memorandum by the Confederation of British Industry**

#### CBI RESPONSE TO CALL FOR EVIDENCE: SCIENCE TEACHING IN SCHOOLS

Business demand for higher skills continues to grow in today's competitive global market. The significance of skills in key areas such as science cannot be underestimated when it comes to maintaining a competitive advantage. The 2002 Roberts' Review of science, engineering and technology skills focused on the need to ensure an adequate supply of skilled people for businesses conducting R&D in the UK. This point was reaffirmed in a recent DTI Economics Paper on Science, Engineering and Technology skills<sup>11</sup>. R&D is recognised as being one of the core factors affecting innovation, and thus productivity and competitiveness.

Providing improved support for Science, Engineering and Technology (SET) education at higher levels becomes even more pressing when emerging markets such as China are putting huge resources into producing high-quality science and engineering degrees—one third of China's graduates receive engineering degrees—compared to only 8% in the UK. If the UK is to maintain and enhance its competitive edge as a modern, innovative high-value economy, then the quality of science and engineering must remain renowned.

Research in England suggests that the decline in interest in school science starts in late primary school—around the age of 10<sup>12</sup>. Suggestions for the decline in enthusiasm towards science include: a lack of experimental work, preparation for national tests, and difficult science curriculum content<sup>13</sup>.

A good supply of high quality science teachers is crucial to inspiring young people to pursue STEM studies and in achieving results in the classroom. While there have been some improvements in the recruitment of new graduates and career-changers into science and mathematics teaching, evidence suggests that there remain some issues of real concern.

<sup>11</sup> DTI Economics Paper No 16, Science, Engineering and Technology Skills in the UK, March 2006.

<sup>12</sup> Primary science in the UK: A scoping study. Final Report to the Wellcome Trust (April 2005), 75.

<sup>13</sup> Primary science in the UK: a scoping study. Final Report to the Wellcome Trust (April 2005), 75; Gilbert, J (Ed) (2006) *Science Education in sChools: Issues, evidence and proposals*, TLRP: London.

### NUMBER OF SPECIALISED TEACHERS IS FALLING—AND QUALITY MAY BE SUFFERING

At GCSE level 30% of physics teachers do not have an A-level in the subject. The situation is worse at key stage 3 with over 75% of teachers teaching physics at KS3 not having studied a physics oriented degree and 40% not having an A-level in physics, 14% teaching biology not having a biology A-level, and 20% teaching chemistry not having a chemistry A-level. The vacancy rate for teachers of maths and science is some 50% higher than the average vacancy rate for other secondary school subjects.

This phenomenon, of teachers teaching outside their area of expertise, has been increased with the introduction of the Double Award for Science GCSE since schools often prefer this to losing continuity in the classroom.<sup>14</sup>

Those teaching science might not be the most academically qualified. Around 70% of new recruits to teacher training in 2000 for history had degrees at 2:1 level, only around 44% of those applying to teach science did. That is not to suggest that there is a necessary link between degree class and ability as a teacher (communication skills are vital to teaching—and can be lacking in some highly qualified scientists and mathematicians), but recruitment into the teaching profession is from the same wide pool of talent.<sup>15</sup>

### TEACHERS TEACHING OUTSIDE THEIR SPECIALISM OFTEN STRUGGLE TO ENTHUSE—TEACHING OFTEN BECOMES MORE DIDACTIC<sup>16</sup>

This is not a question of ability—many teachers are very able to teach subjects outside their specialisation—but educationalists agree that what is often missing is the enthusiasm to try different teaching techniques and to inspire.<sup>17</sup> More than twice as many UK head teachers than head teachers in other OECD countries believe that teacher shortages or inadequacy are adversely affecting pupil performance in maths (almost 30%) and science (almost a quarter).

Students cite their enjoyment of a subject as significant in choosing whether or not to continue with it to A level. In recent research, 70% of GCSE students asked said it was a “very important” factor, a further 26% said it was “important”. Liking a teacher was also key for those students when it came to making choices for further study—19% stating it was “very important” and 54% “important”.<sup>18</sup> Clearly in this context it is vital, if we are to develop the next generation of scientists, to enthuse young people—and to ensure a good and creative quality of teaching.

A number of practical steps should be taken to enthuse pupils about science subjects:

- Greater efforts should be made to introduce practical science demonstrations throughout the key stages. But demonstrations have to move on from one or two eye-catching events. It is essential that day to day teaching is interesting and meaningful.
- Government should focus on making links with active scientists in business to come into the classroom and enthuse children.
- Government should continue its enhanced recruitment and retention packages for science teachers (eg Golden Hellos).
- Careers advice for GCSE students should pick up on opportunities for the use of science in their future careers—directly in science and engineering jobs and indirectly in jobs supporting science-based companies. It should give students a clear idea of which subjects they should take and which science degree they should obtain if they wish to pursue a science career.

June 2006

### Memorandum by Francisco DaCosta

As a science teacher of 14 years standing, specialising in physics across Key Stages 3, 4 and 5, I have become disillusioned with both the conditions of the “ancient” laboratories and the even more dated scientific apparatus. Having taught in schools from Tower Hamlets to Staffordshire, school labs reflect the second rate investment that is held by government and society.

<sup>14</sup> Roberts Review—Sir Gareth Roberts, *SET for success: The supply of people with science, technology, engineering and mathematics skills* (April 2002), 56.

<sup>15</sup> Roberts Review—Sir Gareth Roberts, *SET for success: The supply of people with science, technology, engineering and mathematics skills* (April 2002), 55.

<sup>16</sup> Parliamentary Office for Science and Technology—Primary Science (September 2003).

<sup>17</sup> Roberts Review—Sir Gareth Roberts, *SET for success: The supply of people with science, technology, engineering and mathematics skills* (April 2002), 57.

<sup>18</sup> Siemens research.

To address the poor environmental conditions of my “laboratory”, I endeavour to find strategies that make my subject more engaging to my young charges eg:

- (1) travel 280 miles round trip from Staffordshire to The University of Wales, when funding and cover costs permit;
- (2) beg, borrow and steal second rate equipment from other schools in the area;
- (3) invite as many outside agencies as possible to show “real” science eg Institute of Physics Lab in a Lorry;
- (4) decorate my laboratory, within limits, and try to sand the benches down after 35 years of graffiti; and
- (5) find funds to pay for the NEXT set of textbooks for the NEW specifications and re-write another scheme of work whilst trying to implement the Key Stage 3 and 4 specs.

The learning environment must have an aesthetic element, as well as the apparatus to be able to teach conceptually difficult aspects of science. If the government wants to recruit more students into Key Stage 5, then LOWER the number of students in Key Stage 3 and 4 as 30 to 35 Year 10s doesn't give you enough room to swing a cat, let alone a pendulum to show simple harmonic motion.

*May 2006*

### **Memorandum by Tom Dawson**

#### **MY BACKGROUND AND CONTEXT**

I started teaching in 1990 and have taught in a mixed 11–18 comprehensive, a private/state girls' school in Malawi where I also co-ordinated some work for the ODA, and now teach at an 11–18 boys' grammar school which is co-ed in the sixth form. I started teaching both Physics and Chemistry to A-level and now am focussed on Physics. 50% of my Y11 choose to study Physics at A-level. 2/3 of my students score A\*/A at GCSE and 60% A/B at A-level. The majority of my A-level students opt for a science/engineering degree. At KS3 last year all but two of my pupils scored level 7. The value-added scores put my department in the top 5% regularly and in recent years have frequently topped the Physics Olympiad medals table for state schools. I have just started working with the IOP as Physics Enhancement Project co-ordinator for the West Midlands where I have the pleasure of working with some truly good professionals empowering mature students from a variety of science related backgrounds to deliver up to A-level Physics with confidence. I am also working with my LEA to raise the bar with exiting science teachers in the authority who are asked to teach physics but do not have a science background. If you would like to engage me in a consultancy role, please do get in touch.

#### **THE CALL FOR EVIDENCE BULLET POINTS**

##### *The current situation*

- The numbers of teachers in physics, biology, chemistry and mathematics, including the numbers teaching outside their specialism.
- Regional variations in the supply of science teachers.
- The retention levels for science teachers.

We have found it increasingly difficult in recent years to recruit good quality teachers in particularly physics, chemistry and mathematics—and I teach in a grammar school in a nice market town in Shropshire. Once on board we do not have a problem keeping hold of staff but recruitment of quality is our biggest issue. The school ethos is to deliver three separate sciences down to year seven, because it works. My results and aspirations are replicated across the department. There needs to be a stronger recognition from government effectively communicated to headteachers and curriculum planners that there is not single subject called science. Dual Award Science has caused incredible damage to standards at GCSE and the consequence impacted at A-levels and beyond. My work with the LEA reveals large numbers of teachers who are great with Biology being asked to teach Physics. They are nowhere near similar. Spanish, French and Italian have far more in common than Physics, Chemistry and Biology. So why do we not have dual award modern languages? Your questionnaire reveals the on-going ignorance by labelling colleagues “science teachers”. Biology involves an awful lot of vocab. There are many facts to learn and many processes to learn. Physics is entirely different in its approach. Physics asks why? much more than biology. There is less knowledge but much more understanding. It is a different culture. Physics does not now include A-level maths to enable A-level physics but it is precise and

there will be more of a mathematical content than biology. Training biologists to teach physics myself reveals a need to develop quantitative thinking. If I double frequency of a wave, what happens to its wavelength. I find many biologists aka scientists struggle with this fairly basic question in physics. When the government is asked questions about the number of physics teachers, it always responds with numbers of science teachers. Why?

#### *Attracting science teachers*

- The incentives that exist to attract new graduates and those from other professions.
- Other measures that could be taken to increase teacher numbers.
- The effectiveness of teacher training in science subjects.

Conducting class experiments has become a huge burden. Health and Safety is burdensome where confidence amongst teachers is lacking; indeed H&S has become an industry in its own right stifling excitement. I also have a passion for taking kids out on expeditions and received adequate training to do so but H&S means I cannot anymore take out kids on Silver D or E expeditions, only Bronze even though nobody nationally has died on a Silver expedition (as far as I know). The culture of putting up umbrellas needs to be tackled if adults are to be prepared to involve children in anything to do with risk.

Discipline in class is also an issue, particularly where experiments are involved. There are many occasions when practical work can light kids imagination like nothing else. However, those biology teachers I have worked with do not want to use electrical equipment or Bunsen burners with disruptive pupils for fear of being held responsible for the consequences of badly behaved children. I agree with inclusion, but when does this provision put the responsibility on the child to include themselves? Behaviour management is such an issue that this becomes more of a focus than teaching. If adults can be convinced that they can actually get on and teach the majority of pupils who do want to learn, then they will join and stay.

#### *Teaching science*

- The adequacy of professional support for science teachers.
- The effect of changes in the curriculum on attracting/retaining science teachers.
- The impact of existing schemes designed to help generate enthusiasm in young people for science subjects.
- The role of the practical in teaching science.

There exist plenty of resources to help teachers and the ASE aspires to be creative and innovative with teaching techniques. The curriculum has become so dumbed down over the years that it is purile. The proposed GCSEs continue to lack rigour as far as physics is concerned and this will further undermine A-levels. When Curriculum 2000 was introduced, I looked at the syllabus teaching points for A-level physics. 16 new teaching points were brought in (even if they had appeared in the old CSE mode 3 syllabus) but over 120 teaching points (including the “harder” mathematical points) were removed. This is not raising standards. The huge variety of GCSEs mean that the base core for GCSE is reduced further and this will cause further dilution of A-level standards. Rather than inspiring me to teach, I feel like leaving the profession entirely because of this drive to celebrate the mediocre. There are good kids out there who are being failed by not being stretched or set up for high standards. Dual award resulted in the four year degree as standard. What will these changes do?

Where schools do have a physics specialist, they are often alone in the school and have no form of mentoring. My work with the LEA is getting responses like, “I didn’t know that was possible”. If teachers don’t know what can be done and what high standards really are (in terms of lesson content not how glossy the lesson can be made to look) then how can pupils be inspired to make this country the best? I am aware that sixth form provision in schools is often very book driven without demanding students to think. There needs to be support to release colleagues to be challenged. In my school we have three lower sixth and three upper sixth physics sets. One thing we do as teachers is to teach each other the core syllabus. Not because we don’t know it but because it stimulates us to ask more demanding questions of each other. Most schools do not have this luxury and I suppose this is the old adage “success breeds success” but if we cannot create the stimulus for teachers to sharpen each other somehow then we should look at ways of doing so.

There are schemes which do offer incentives for involvement and I admire the aspirations of the likes of Rolls-Royce to make a positive impact in education. However, these schemes are always filtered by teachers themselves before they reach the pupils and the question one always asks oneself is “do I have the time to oversee this?” I do not engage in such schemes for this reason. The single major contributing factor for

generating enthusiasm in science subjects is the role model of the teacher in front of kids. If the teacher can communicate genuine zeal and passion for their subject and a passion for sharing this with others, the stuff any strategy, kids will get on board end of story. It's really simple, if we enjoy what we do, others will want to do it with us! Now here is the issue: We have colleagues being asked to teach out of their specialism. Consequently they lack confidence. This comes across to kids that this is really hard. Now if the teacher finds this hard, what hope has the pupil got in perceiving success in that field? On the other hand my line with pupil is often "physics is really easy, honest. And it is fun too." I do some work with them, give them an A-level question to do (when they are in Y7) but don't tell them. Then when they get 7/10 or so, I show them the paper I copied it from and tell them that exams really aren't all that much to worry about so let's do some physics and the exams will take care of themselves. In fact I regularly finish teaching sometimes as much as half a lesson before they go down for study leave. I rarely do past papers with them in class to prime them to pass exams—that is all on our website with markschemes so they can use their time for that. They seem to do pretty well when the exams do come around. (I refer to my first paragraph). I do not put this to sound arrogant. I simply wish to assert and illustrate that enthusiasm and passion are absolutely key. The work of the IOP with the Physics Enhancement Project is a fantastic example of a relatively low cost but powerfully effective tool to make a difference. Graduates with a science background are given an incentive to learn physics (the physics taught in schools) to a standard higher than A-level. The tutor I have met at Keele is very creative at linking physics to life experience and life experience to physics. In six months, these graduates will be given the confidence to know the subject really well and have an answer for any question a pupil might throw at them. That is really empowering when the next step is PGCE or GTP/EBR.

### *Schools*

- Variations between schools in the teaching of science, including specialist schools, academies and Community Technology Colleges; procedures for exchange of best practice.
- The condition of school labs, and the provision and use of lab technicians and teaching assistants.
- Links between schools, universities and industry, to facilitate science teaching.

I cannot comment on variations other than my own experience. However, specialist colleges is really a hoop-jumping exercise for most schools to secure a bit more cash. Why spend so much money inventing and monitoring the hoops. If all schools are supposed to become specialist anyway, why not just give them the cash and release them from the huge amount of time preparing these ridiculous bids in the first place. Many schools with a specialism are not very good in that specialism anyway because one huge hoop to jump through is to demonstrate year-on-year improvement. That is most easily achieved by the worst performing department isn't it? So the best kids in the country in that field are going to be taught by the worst departments? (Perhaps I am going too far and being a little unfair here, but I think you have got my drift.)

Some feel the state of equipment matters. We are about to have new labs built because we simply do not have enough space to teach in labs. Having said that, the 1950's existing labs are adequate for what they do (in use > 100% of school curriculum time) and again what matters is not how glossy we can make things look, it is the enthusiasm of the teacher. My time in Malawi was probably my most rewarding. I had a departmental budget of £500 for the year for 400 students and this was to cover the whole faculty! What mattered there was attitude. In this country we are too materialistic. If the teacher is enthusiastic and the kids are up for it, resources are not an issue, really. We were behind in the syllabus when I arrived and so offered the opportunity of extra lessons. 79 out of 80 pupils came for extra lessons starting 8 am finishing 12 pm for six Saturdays in a row. They knew and appreciated the opportunities put before them. Here we expect things to be given on a plate and we do not understand that success is often spelled W..O..R..K.. H..A..R..D. Lab technicians need to see that their week does not entirely get described by the weekly equipment list. They too need to see that spontaneity needs to exist in the department which will call on kit to be required at extremely short notice, just to prove a point. I hear a lot of stories about technicians being inflexible.

Links between schools and universities and industry make a difference in that aspirations can be raised. Kids can see possibilities for themselves. I often ask Oxbridge students to come back to speak to our sixth form and GCSE groups so that they know what is necessary to get there and to succeed as well as the rewards waiting for those prepared to put the effort in. As a school we also link with some local firms. These links are positive and need encouraging but remember the time issue. the teacher will want to do a good job and if all departments had too many links, schools would end up spending too much time on trips out and not enough time in the classroom.

*June 2006*

### **Memorandum by Emma Drewery**

#### **EFFECTIVENESS OF TEACHER TRAINING**

Due to incentives we now seem to be getting ex-industry workers who find it difficult to relate to “today’s student”. Science ITT students in particular have a discipline (Chem, Phys, Bio) and are often very poor at teaching outside their discipline.

#### **THE ADEQUACY OF PROFESSIONAL SUPPORT**

The professional support for science teachers is limited and the majority of courses run are expensive and not within our geographical region, which makes travelling expenses high. This means that our school is reluctant to send us out for training.

#### **THE EFFECT OF CHANGES IN THE CURRICULUM ON ATTRACTING/RETAINING SCIENCE TEACHERS**

The changes in the curriculum are good for the students, but has meant that teachers have to adapt to the new specifications very quickly, and with little or no support, resources or funding.

#### **THE ROLE OF THE PRACTICAL IN TEACHING SCIENCE**

Practical sessions are the reason why students enjoy science, but rising class sizes have meant that practical sessions can be potentially dangerous. Why can’t science have a recommended maximum class size, like Technology?

#### **THE CONDITION OF SCHOOL LABS, THE PROVISION AND USE OF LAB TECHNICIANS AND TEACHING ASSISTANTS**

Our labs are too small, and with no “guidelines” our principal does nothing about the fact that we are trying to teach 30+ students in a lab that was designed for 16 students 20 years ago! Our technician time is insufficient, but the “Senior Management Team” just see them as glorified “washer-uppers” and do nothing. We have one teaching assistant in our department, bearing in mind that eight classes could be on at the same time.

Overall, Science comes in a poor fifth to English, Maths, I.C.T and Technology!

*June 2006*

### **Memorandum by EDU-LAB Ltd**

#### **EDU-LAB SUBMISSION IN RESPONSE TO CALL FOR EVIDENCE: SCIENCE TEACHING IN SCHOOLS: THE ROLE OF THE PRACTICAL AND HOW MICROSCIENCE CAN HELP**

##### **I. BACKGROUND**

We at EDU-LAB believe that it is not possible to learn—and therefore teach—science unless the student can be given the opportunity to “do science”. Practical work is probably the most important part of teaching the subject: it is the defining characteristic of science learning. It involves the student in what is going on, arouses his interest and keeps his attention and, because it is totally relevant to every aspect of everyday life, can stimulate a wide ranging desire to experiment further.

We would like to propose that consideration be given to a solution using a unique system of Microscience equipment with curriculum linked worksheets and guides. It involves a revolutionary approach which changes practical work to neat, compact and efficient procedures.

A recent study carried out by UNESCO revealed that most schools do not do anywhere near the amount of practical work that they should. Reports of concern continue to illustrate that the number of science qualifications is reducing. This is found at all levels in education systems around the world.

## II. CHALLENGES FACING SCIENCE TEACHERS : LACK OF PRACTICAL WORK

Some of the hindrances that face teachers at both Secondary and Primary levels are:

- lack of suitable laboratory facilities
- lack of specialist training
- safety risks pertaining to personal and environmental issues
- length of time needed for practical work
- lack of time
- insufficient worksheet material
- lack of teacher support.

These hindrances are aggravated by factors such as:

- costs
- old fashioned experimental techniques
- dated equipment
- negative perceptions caused by demonstration of experiments.

## III. RESPONDING TO THE CHALLENGES

Microscience techniques alleviate all of these challenges to effective delivery of practical science. EDU-LAB has been driving and co-ordinating the microscience approach for the last 12 years, and are pleased to have had some real success in bringing practical science experience to large numbers of children. Alongside the benefits to the students, microscience techniques and equipment overcome the problems of cost, lack of facilities, time and safety, and the worksheets bring fresh, new, relevant topics to the students. Teacher guidance and support are also available. With microscience, practical science is coming back into our schools.

We would like this process to be speeded up to meet the compelling needs of the 21st century.

In order to increase momentum on this initiative, we are now at a stage where support from an influential body like the House of Lords Select Committee on Science and Technology would prove beneficial. We give examples below on how this might be achieved.

## IV. MICROSCIENCE APPROACH TO PRACTICAL WORK

### *The Global Picture*

Microscience is being adopted throughout the world as a method both to allow effective practical science in schools and universities and to enable industry to meet the challenge of increasing difficulties with safety and environmental protection.

Industry has given a clear lead in its approach to laboratory work and is perhaps the best source of inspiration. Broadly speaking, by “going small”—using minute volumes of chemicals and reagents—industry has created new opportunities for practical work at a lower running cost. The huge strides made by the medical and research laboratory fraternity have been fuelled by:

- the HIV crisis
- great strides in medical diagnostics
- rapid development of DNA research and diagnosis
- advancement of forensics investigation techniques
- greater understanding of molecular biology and biotechnology techniques in general.

Clearly this new direction for science needs to be more formally embodied in the science learning process if we are going to excite and enthuse potential scientists. Taking this into account, a project was conceived and instigated in 1994 which involved bringing these techniques into practical science teaching. This project has involved hundreds of academics and research institutions worldwide, in which several million students have participated.



*The UK Perspective*

Microscience has been strongly supported by the most prestigious bodies in science education, including the Royal Society of Chemistry and the Association for Science Education. The “Whodunit Event” in 2003 organised by Planet Science in conjunction with the DfES brought these techniques to around 30,000 schools in the UK.

It is a simple system which nevertheless has the sophistication needed to meet most of the requirements of examination specifications to AS and A levels as well as exciting students at KS2, KS3 and KS4. Of greatest significance is the potential of microscience to enthuse students, allowing each one to have meaningful hands-on experience.

Experience shows that school students find microscience to be both refreshing and a real aid to understanding. Teachers who have used it are excited by its potential to revolutionise teaching and learning and to free up precious time by greatly reducing the time required for practicals. Senior Managers are interested in the reduced need for laboratories and substantial savings in costs and storage. Where technicians are in short supply, microscience can overcome the often consequential limit to practical work as preparation and clean-up require very little time.

Microscience is continually being refined and expanded.

Schools using the new video-conferencing route to teach AS and A chemistry and physics will have microscale practicals built into the course and materials supplied as part of the package.

Now, for the first time, microscience techniques are being included in the Schemes of Work, textbooks, and In-Service training programmes. Groups such as QCA, OCR, Edexcel and AQA, as well as the Welsh and Scottish education authorities, are taking up microscience as an excellent option for practical work in science. Science Learning Centres and some Universities are also involved in the programme. The programme uses items of equipment that are used in the real world, and comprises the following key elements:

- microscience equipment items
- microscience kits of equipment
- worksheets geared to the national curriculum
- guides for teachers
- teacher training programmes.

## V. BENEFITS OF THIS APPROACH

Some of the benefits at both primary and secondary level are listed below:

- Accuracy of results
- Safety—in use and in waste disposal
- Systematic lab procedure
- Since the quantities are so small, they make minimal demands on technician time, even at A Level
- Chemical reagents are available in volumes and concentrations needed, making a substantial difference to preparation time
- Experiments are far less time-consuming and avoid large amounts of waste
- Washing-up is simple and storage space is a fraction of that required for traditional practicals
- Low cost—savings on apparatus and chemical costs
- User friendliness
- Children quickly learn the techniques needed to work in small scale, they have often much greater manual dexterity than adults and enjoy the clarity of results, uncluttered by normal laboratory paraphernalia
- Rapid procedures
- Individual ownership
- Increased motivation for both students and teachers
- At primary level there are both general and topic-specific kits, including worksheets, which considerably reduce teacher preparation time.

We are also attaching a summary of the Advantages of Microscience drawn up by Dr Mike Wooster based on his personal experience in the secondary school teaching environment.

## VI. OUR REQUEST

Based on the success of the microscience project in hundreds of education systems worldwide, we feel it needs to receive attention in the following forms:

1. Awareness of this approach should be created within the Science education system.
2. A study should be commissioned to determine the best way forward to implement microscience practicals throughout the UK education system without delay.
3. Funding should be considered to enable schools to have access to these new techniques.

We believe that this has the potential to significantly assist the reversal of current trends away from science learning.

## VII. ORAL EVIDENCE

Should we be invited to give evidence, we would provide a brief insight to the microscience system by demonstrating it in use.

## VIII. SUPPORTING DOCUMENTATION

1. Example of an Edexcel Worksheet (Photosynthesis)
2. *Advantages of Microscience* by Dr M J Wooster.

### **Memorandum by the Field Studies Council**

1. The Field Studies Council (FSC) is a pioneering educational charity committed to bringing environmental understanding to all. Established in 1943, the FSC has become internationally respected for its national network of 17 education centres. The FSC provides informative and enjoyable opportunities for people of all ages and abilities to discover, explore, be inspired by, and understand the natural environment.

2. The FSC welcomes the opportunity to contribute to the inquiry into science teaching at schools and continue to promote the importance of fieldwork, specifically within the science curriculum, and the barriers which currently prevent its full benefits from being realised.

3. Good quality residential fieldwork helps to improve education standards. Despite this, fieldwork provision in science and biology is declining in British secondary schools. A minority of 11–16 students will now venture outside the classroom and even in A-level biology nearly half the students will do no fieldwork, or will only have a half-day experience near to their schools. Residential science fieldwork is available to fewer than 5% of GCSE students and this provides a stark contrast with other subjects such as history, music and geography where the levels can be 10 times higher.

4. FSC believes that the decline in educational field visits has a negative effect on the number of pupils choosing science at A-level and that if the government is serious about its commitment to attract more science teachers, science needs to be made more attractive to GCSE pupils and a-level students. Recent surveys by the Science Museum and Awarding Bodies have shown consistently that practical hands on activity, visits and excursions are the most enjoyable aspects of science education. Yet, these are the very elements which are most at threat. The potential for such activities for recruitment to the subject is valued much more highly by teachers in other subjects, in geography for example.

5. The decline in science fieldwork is now extending to universities and appears to be leading to a shortfall in people with the practical skills needed to support biodiversity and teaching related careers and activities. It also undermines the potential to raise the level of informed environmental awareness at a time when there is an increasing demand for students, volunteers and the general population to be aware of their impact on the world around them. This is a strategic weakness for the government because a great majority (76%) of its biodiversity field programmes—including those which are meeting EU statutory compliance needs—are dependent on volunteers.

6. Fieldwork can make a real difference in enthusing and inspiring young people to take up the science at A-level and at university. It helps students to develop their understanding of science as an evidence-based discipline and to acquire the hands-on experimental skills that are an essential part of scientific inquiry. More importantly, there can be reinforcement between the affective and the cognitive, with each influencing the other and providing a bridge to higher order learning<sup>19</sup>. FSC therefore strongly encourages the inclusion of a

<sup>19</sup> A Review of Research on Outdoor Learning, National Foundation for Educational Research, March 2004, page 2.

fieldwork element within the Science national curriculum for GCSE students and would like it to be made a mandatory requirement for all A level biology students.

7. As part of London Outdoor Science, a two-year project to develop the use of local sites for secondary science fieldwork, 60 secondary schools in 5 Inner-London boroughs were surveyed to assess current levels of science fieldwork using local sites (including school grounds). Evaluations of the project have shown that, despite the repeated offers of external support by an experienced secondary science teacher to help schools in developing local fieldwork opportunities and provide some school-based or local training for science teachers, only a quarter of the schools in the five borough project have responded.

8. Of those that did not respond, the key barriers quoted for not doing fieldwork in science lessons were lack of time within the syllabus/timetable, limited staff knowledge/expertise, limited school equipment, lack of school grounds, time consuming administration to complete before even attempting field trips; finances, health and safety and administration, curriculum objectives for outdoor work limited at key stage 4, pupil behaviour and staffing cover difficulties.

9. Fieldwork provides an opportunity for teachers to develop a different and, potentially, more positive and productive relationship with their students. The dynamics and interrelationships developed whilst working in groups can have a huge influence on how students develop socially. This is particularly true for residential experiences.

10. FSC was supported in this view by the House of Commons Education and Skills Select Committee Report on Education Outside the Classroom which was published in 2004. The report said: “outdoor learning can benefit pupils of all ages and can be successful in a variety of settings. We are convinced that out-of-classroom education enriches the curriculum and can improve educational attainment.”<sup>20</sup>

11. FSC is concerned that fieldwork skills are no longer passed on to science teachers as part of an informal ‘mentoring’ process. As a result, these skills could be lost entirely as older teachers leave the profession. The DfES should therefore engage teachers’ professional bodies and subject associations in the provision of fieldwork training for science and geography teachers and ensuring that appropriate programmes of professional development are on offer to all those teachers who might benefit.

12. FSC organises field trips for 11–14 year olds for London secondary schools through the London Challenge project. Interviews with participating teachers and pupils have shown that there is increased co-operation between pupils with new friendships being established; improved relations with teachers; increase in knowledge and skills base. Most significantly, those pupils who often demonstrate challenging behaviour are reported to have improved attention and show participation back in the classroom.

13. The government has identified Science Learning Centres (SLCs) as being key to the delivery of fieldwork training and continuing professional development to teachers. The FSC has engaged fully in the important opportunity that SLCs offer; developing and running a number of CPD courses. Despite securing grants from the British Ecological Society to cover all costs to teachers, we have been disappointed that almost all courses have cancelled due to low take-up teachers.

14. We support the Schools Minister’s decision to reconsider the status of outdoor learning within Initial Teacher Training (ITT). We support the House of Commons Education Select Committee view that the DfES should work with the Training Development Agency to ensure that ITT and CPD courses demonstrate the potential benefits of education outside the classroom and point teachers towards ways to develop their skills in this area as their career progresses. We also welcome the government’s forthcoming Outdoor Learning manifesto. We are concerned, however, that science fieldwork may not benefit from these initiatives unless changes are strongly driven by policy, and supported by adequate resources and training.

15. The profile of fieldwork needs to be raised; OFSTED should conduct spot inspections on quantity and quality of fieldwork provision and fieldwork should be included in school Self Evaluation Frameworks.

The FSC therefore proposes that:

Curricula must acknowledge the importance of fieldwork in helping to deliver learning outcomes in science teaching. The need for fieldwork should be strongly encouraged at KS3 and GCSE, and mandatory for A-level students. OFSTED should conduct spot inspections on quantity and quality of fieldwork provision and fieldwork should be included in school Self Evaluation Frameworks.

The TDA, SLCs and Association for Science Education should be encouraged and supported to build the competence and confidence within science teaching to deliver high quality fieldwork—the strongest way of bringing the subject to life.

*June 2006*

<sup>20</sup> Education Outside the Classroom, House of Commons Education Select Committee, February 2005.

### Memorandum by Mr Jules Hoult

#### SCIENCE TEACHING IN SCHOOLS

##### *The Current Situation*

1. The shortage of physics specialists in the state sector is well documented. What is not so well known is the difficulty independent schools are now having recruiting physics teachers despite longer holidays, higher salaries and the promise of only having to teach physics rather than science in well maintained and resourced laboratories.
2. Increasingly, appointments are being filled by teachers from the state sector. This is likely to increase as many independent schools have moved to the IGCSE courses for science and mathematics; these courses do not have the loathed practical investigations (Sc. 1).
3. In prep schools although much of the teaching is science rather than separate subjects there is a similar predominance of biologists and chemists.

##### *Attracting science teachers*

4. There has been a slight recent increase in the numbers of students training as physics teachers but a decade of PGCE Science courses packed out with biologists will take a lot of recovering from. Initial indications are that the Physics Enhancement Project is successfully allowing a career change into physics teaching.
5. A major disincentive to becoming a physics teacher seems to be the nature of the PGCE course. At present it is not possible to train as a physics teacher but only as a science teacher with, at best, a specialisation in physics.
6. This is off-putting to many physicists who have traditionally followed Rutherford's belief that "there are two types of science: physics and stamp-collecting" but also off-putting to the many engineers who express an interest in becoming teachers. Engineers have large areas of physics to learn before they can teach A level: astronomy, cosmology, quantum mechanics, particle physics etc. The thought that they will also have to learn large amounts of biology and chemistry proves too much and there is anecdotal evidence to suggest that a large number become trainee maths teachers instead and never move back.
7. Allowing pure Physics or Physics & Maths PGCE courses would help. Unfortunately at present, some PGCE tutors actively discriminate against physicists because of the requirement to teach across all three sciences in order to qualify:

"I don't like Physics students. They don't have the soft skills I need. I prefer Life Science students. I'll only take a Physics student onto the PGCE if they put in an extremely strong application."

"I would have to think hard about a physics application with physics, maths and further maths at A-level."

##### *Teaching science*

8. The constant changes to the curriculum do not make teaching science an attractive option. Teachers are generally not anti-change and certainly not physics teachers: the *Salters Horners and Advancing Physics* A levels have both been very successful despite requiring a radical change in approach from many teachers. These courses reflect modern best practice and improvements that modern technology allows in teaching.
9. Most of the change that is inflicted on us, however, is ill-judged, poorly managed and very rushed. Several examples are currently worrying teachers across the sciences.
10. The new KS4 specifications start teaching this September. Only one of these courses, OCR's *21st Century Science*, has been properly piloted and what is now being released to school is a vast improvement on the material that was available to pilot teachers. The other courses still have all their errors, uncertainties and unfortunate teaching orders. Concerned groups have pointed these problems out to the awarding bodies but due to the timetable that QCA has imposed they do not have the time or inclination to solve them and QCA does not seem able or willing to force them to do so.
11. Some schools are already reporting problems getting to grips with vague syllabus statements that give no indication of what level is required for examination and teachers entering the profession must be finding this very intimidating. In schools with no physics specialist these problems are likely to go unresolved and the quality of what is offered to pupils will suffer encouraging even fewer students to continue post-16 with a subject that even their teachers cannot make sense of.

12. The independent schools have largely voted with their feet and are running International GCSE courses in science and mathematics. These courses may not reflect the most up-to-date content but these awarding bodies make a major selling point of their promises that they have not and will not change them. Schools are thus able to spend time getting to grips with them and deciding how best to teach them over a number of years; no teacher ever teaches a new topic perfectly first time but as a pilot teacher of *21st Century Science* using pilot material I was taking part in the assessment of the course before my first cohort of students had sat their exams!

13. At KS5, QCA has proposed changes that will apply across all A levels. Nobody, including a physics subject officer from QCA has managed to explain to me how these could possibly benefit physics. They will require major reworking of both the *Salters Horners* and *Advancing Physics* courses at large expense to the charitable institutions that developed them and there is a real danger that practical work may no longer be examined. The Institute of Physics has orchestrated a major campaign against these changes but at the time of writing the result is unknown.

14. Independent schools are again looking elsewhere and the international exam boards know a good market when they see one: there will be a suite of “pre-University” qualifications available shortly. Neither IGCSE nor these pre-University qualifications are QCA-approved and are therefore not available to the state sector so there is a real danger of a two-tier qualification system developing.

15. QCA has also started preparing to change KS3. How KS3 can prepare pupils for KS4 when it is not yet known how the changes at KS4 have worked out is not clear. The timescale is again very tight and although this age bracket would benefit from a major overhaul there does not seem to be time to do much more than tinker. A draft list of topics for physics looks very dull and is unlikely to inspire pupils or teachers. A chance to do something innovative could well be missed as it would take several years to develop and pilot a proper rewrite of KS3 and there does not seem to be the political will to allow that to happen.

16. Practical work and investigation is an essential and hugely enjoyable part of science teaching and learning at all levels. The proposed changes at KS5 however could have the effect of decreasing the amount of practical work done unless a school makes a very positive commitment to what is one of the most expensive parts of the curriculum.

17. The proposed changes to the number and nature of assessment units at AS and A2 means that it is impossible for a course to be modular and still have practical assessment. Currently there are six assessment units over the two year course so it is possible to have an assessment unit exam at both the January and June sittings and a coursework unit in both years. If only four assessment units are permitted something has to go. Modularism and the ability to retake modules are very popular with pupils; dropping them would make the sciences look less attractive, particularly for those who need top grades to get into highly competitive courses. Dropping practical assessment from science A levels could lead to schools coming under financial pressure not to do practical work. This would certainly make science teaching less attractive to both pupils and teachers.

18. The decline of the sciences post-16 is serious but not yet terminal. Science continues to interest pupils of all ages and ability but science courses manage to put many of them off. Some of the current changes at KS4 may well improve matters but it will be a few years before these courses bed-in. This time should be spent taking a long term review of KS3. KS5 does not require any major changes. A public commitment to long-term stability in science teaching by the government and more flexible training courses may well encourage more people into considering teaching.

June 2006

#### **Memorandum by the Institute of Food Science and Technology**

Many of the areas where the Committee is seeking evidence will be covered by other professional bodies and learned societies.

My purpose is to bring to your notice the effects of the decline in the number of A-level science entries on an important science-based sector, the food profession.

The food profession is composed of persons in the food processing and retail industries, academia and the public sector and the problem is best illustrated by reference to the food industry. The UK food and drink manufacturing sector is the single largest manufacturing sector in the UK. It has a turnover of £69.4 billion, accounting for almost 16% of the total manufacturing sector. It employs an estimated 650,000 people in around 7,300 firms. Hence, it is a very significant part of the UK economy. The leadership, management and innovation required in this industry is provided in the main by science and engineering graduates many of whom are specialists in Food Science and Technology. A recent project undertaken by IFST, the Science Council and Improve Ltd (the Food & Drink Industry Sector Skills Council) to examine the demand and supply of Food Scientists and Technologists showed:

- There is an increasing demand for Food Scientists and Technologists over the foreseeable future.
- More than half the employers surveyed said there is a shortage of people to fill such vacancies and this is due to a supply problem.
- The recruitment process to fill vacancies is taking longer than two to three years ago.
- The most prevalent issue mentioned by employers in recruiting to fill graduate vacancies is quality.

In common with many other science-based professions, the decline in the numbers of A-level science entries is having an effect on a very important industry. In terms of the scope of the current review there would be great scope to use “food” examples to illustrate aspects of science teaching whether in chemistry, biology, physics or mathematics. Although this would require to be done in a balanced way, most young people have an interest in, and an opinion on, many aspects relating to food, eg GM, environmental issues, food safety, pesticides, obesity, vegetarianism, etc, and these could clearly be built in to the curriculum. The clear need is to interest and enthuse young people in science and this could contribute to achieving this goal.

*June 2006*

### **Memorandum by the Institution of Engineering and Technology**

#### ENQUIRY INTO SCIENCE TEACHING

1. In the 2006 Budget, the Government acknowledged calls from many organisations such as ours that urgent support was needed for science and technology in schools. During the budget speech, and in the accompanying documentation, major new targets for improving the availability and quality of science teachers were announced. Ambitious targets for increasing the numbers of students taking science subject were also revealed.
2. We note with concern that there seems to be a discrepancy between the targets for students and the targets for teachers (which logic suggests should be closely allied), and we remain concerned that no detail has emerged as to how these targets will be achieved.
3. Whilst we welcome the Government’s commitment and targets, this Committee enquiry is especially timely, as there has been no announcement on delivery or how to achieve these important changes.

#### COMMITTEE’S QUESTIONS

##### *Current situation*

4. One of the critical issues is the supply of appropriately qualified science teachers. In the past six months, two studies, including one funded by the Department for Education and Skills, have for the first time been able to give a clear picture of science and technology teacher numbers.
  5. Both these reports draw similar conclusions, primarily that we do not have enough teachers with the right qualifications. Concerns have also been raised about the age profile of the existing teachers with physics qualifications.
- University of Buckingham (October 2005)  
<http://www.buckingham.ac.uk/education/research/ceer/pdfs/physicsprint.pdf>
- National Foundation for Education Research (NfER) (January 2006)  
<http://www.dfes.gov.uk/research/data/uploadfiles/RR708.pdf>
6. The Institution has also carried out its own research into the demand for engineers and technicians in industry. This survey is the first time in a number of years that these types of questions have been answered.
  7. The overall message was that technical skills were in short supply and there was no confidence that matters would improve in the short term. We found that 35% of businesses believed they would not be able to recruit enough engineers and technicians to meet their business needs this year, rising to 40% over the next four years. Engineers with 5–10 years experience emerged as the most difficult to recruit.
  8. The survey showed a mixed picture on how “ready to work” people with various qualifications were, with graduates being seen as the most ready. Skills shortages were most acute in the South East and business expansion/diversification was one of the major drivers for recruitment.

## ATTRACTING SCIENCE TEACHERS

9. Attracting more entrants into the profession is only half the challenge; retention is also a major issue. This is something that has yet to be effectively studied, although the NFER report does include a case study (see chapter 10). Therefore whilst the evidence is only anecdotal, we still believe this is a major problem.

10. Best practice in retention—as applied in a typical private sector business—should be looked at. Many of the issues are the same; opportunities to develop and move “up the ladder”, pay and conditions, further training and developing skills are all issues for employees across any sector.

11. One step that must be taken is ascertaining the impact of current schemes. We do not believe that the retention rate of staff receiving “golden hellos” is measured, nor is there a clear picture of the overall impact of these and other measures. Knowing the type of incentives that are effective must be the basis for further activity.

12. We believe it is worth exploring ideas such as:

- Minimum of one science training inset day per year for all primary school teachers.
- Pay: look at differential pay scales to attract teachers for shortage subject areas.
- Pay and conditions: what changes would make the profession more appealing to scientists/technologists.
- Schemes to pay full university fees/offer a “student salary” for engineering and physics degree students in exchange for 2–5 years teaching post-PGCE.
- Retention bonuses—3, 5, 10 years etc—for critical subjects.

13. Government needs to openly discuss pay, conditions, recruitment, retention and training with schools, teachers, trade unions and teacher associations. Although some of these options may prove untenable, everything needs to be up for discussion. Radical solutions may be needed.

## TEACHING SCIENCE AND SCHOOLS

14. Attracting/motivating students to take science is very important, and a number of ideas are worth exploring further:

- Raising the level of Education Maintenance Allowance (EMA) for students on science or technology courses (ie additional £5 per week for those on S&T courses).
- Improving careers advice and guidance to ensure the benefit and possibilities of science are clearer.
- Changing delivery of careers advice—to reach parents more effectively.
- Regarding computing science, there needs to be a greater clarity about the difference between ICT taught at GCE and GCSE level—essentially ICT as a necessary user skill—and the study of computing as an academic discipline. There is evidence that this confusion is contributing to the steep decline in applications for degree courses in computing science and software engineering.

15. With the new science GCSE being introduced from September, getting the right resources and materials into schools is especially important—and will impact on “study experience”.

16. Schools many also face barriers to teaching science. More money is needed for improving facilities—not all schools have modern facilities at present. The Capital programme is set to address this, but with vocational teaching potentially becoming a priority (for example through the Engineering Diploma) there is a potential that the massive investment programme might draw the focus away from “traditional” science needs.

- Guidance on school science experiments must be improved—DfES “exceptional activities” unit is apparently regularly approached regarding permission for perfectly permissible activities.
- Specialist supply cover to allow time for continuing professional development (CPD). Regional/local teams of science specialists could provide cover across an LEA where required (we are aware of a possible DfES pilot).
- League tables can have a particularly negative effect on the take-up of science subjects (where grades are typically lower). This effect must not discourage schools from encouraging science.
- Various issues that create barriers for external experts visiting schools, from company policies to administration of criminal records checks, must be looked at (although child safety must remain a priority).

17. A more general issue is that some schools are simply “non-CPD” schools in which—for whatever reason (school culture or resources for instance)—CPD is not encouraged or supported. Creating a culture of continuing professional development across the entire profession is necessary, especially in rapidly changing areas such as science.

18. Trainee teachers should be encouraged to engage with their subject associations and sponsored to attend conferences and similar events that can establish in them the benefits of continuing development at the start of careers. Support in schools from the top down can help it embed a culture of CPD—for example, changes to the Ofsted criteria could make CPD more of a priority. All of this must be coupled with schools getting the resources and supply cover necessary.

19. Questions should be asked as why the private sector is so much more successful with science. The caveat must be that this could be down to external factors rather than down to differences in teaching or resources.

*Resources provided by the IET*

20. The Institution of Engineering and Technology supports schools and pupils in various ways, including financially and through the provision of materials and resources.

*June 2006*

### **Memorandum by Professor Hugh Lawlor**

Improvements in science learning and attainment require an integrated approach that combines effective science leadership, confident and skilful teaching, relevant and contemporary content, continuing professional development for all staff, appropriate laboratories and equipment, and technician and learning support.

In this short submission it is my intention to focus on the recruitment and retention of heads of science and science teachers in secondary schools, particularly those in urban settings.

Effective science leaders are an essential element of any improvement plan. Leaders need a clearly articulated vision, management skills and crucially the drive and consistent approach to track and react to performance (student and teacher). Leadership of a science department is complicated by the need to deal with a wide range of specialist staff, to be responsible for technician and learning support staff, and to be responsible for risk assessments and health and safety.

It is good leadership and management and effective (clear objectives, excitement, pace, engagement, relevance, etc) teaching that will have the greatest impact on learning and attainment in science. Indeed, it is effective and memorable teaching that often determines student option choices at the beginning of Key Stage 4 and particularly post 16.

Any campaign to recruit and retain science subject leaders and teachers will require some or all of the following:

- Professionally organised recruitment that identifies the attractions of working in generally multicultural urban settings (eg lively and generally responsive teaching groups, high commitment to learning, varied cultural and social opportunities etc).
- Increase the number of Teach First science graduates and target science professionals in industrial settings to enter teaching.
- Incentives to attract and retain leaders and science teachers, eg differential allowances, housing support, additional retention allowance after three and five years in post etc.
- A major incentive would be access and entitlement to high quality professional development—through Science Learning Centres, Association of Science Education, higher education, local authorities, specialist schools and academies trust, and national strategy teams.

An entitlement to CPD could be a major retention incentive (eg £1,500 per year in CPD).

CPD would include activities within and outside the school, joint activities with other schools (within collaboratives, clusters, EiC groupings), and by pairing schools (could be a specialist science school/college and another secondary school).

CPD activities could include systematic retraining/updating in shortage science subjects (particularly physics). New and innovative ways of providing CPD will be necessary, including arrangements that avoid absences from school (this could include sharing models of successful internal school activities and programmes).



- Newly appointed subject leaders and teachers should receive coaching and mentoring support—from local authority staff, strategy consultants, higher education, specialist science schools/colleges staff etc.

Regular and continuing support for new subject leaders and teachers requires intensive direct support by experienced staff, either from within the school or from outside.

- Guidance to headteachers and senior leadership teams on ways of supporting science subject leaders. It is important that line managers of science leaders can challenge, support and share effective practice. Senior leadership involvement can also raise the profile of science in the school through assemblies, science evenings for parents and guardians, and generally by “talking-up” the importance and relevance of science in today’s society.
- Science based industries recognise the need to contribute to the growth and relevance of science teaching in schools (and universities). Several science based companies contribute funds for curriculum materials, CPD and awards. In 2004 the pharmaceutical industry invested over £3.2 billion in R & D, representing 24% of the UK’s total manufacturing industry expenditure on R & D. Without improvements in the UK science base the current level of pharmaceutical activity in the UK will not be feasible. Closer, regular and well briefed links between professional scientists should make science experiences more relevant, contemporary and attractive in schools and universities, and can contribute to the professional development of science teachers and tutors.

June 2006

### **Memorandum by The Mathematical Association**

#### THE CURRENT SITUATION

Whilst the problems relating to mathematics teaching in schools and colleges have many similarities to those of science teaching, there are many particular difficulties associated with learning and teaching mathematics. It has a high profile as a result of its great importance to our society both in underpinning a wide range of disciplines and in providing many of the elementary skills needed in everyday life and in employment. It does need separate consideration, a fact that has been recognised in setting up the Smith Inquiry whose report *Making Mathematics Count*<sup>21</sup> was published in February 2004.

The Mathematical Association, in its evidence to the Smith Inquiry, highlighted three key issues which are closely interrelated. These are reproduced below and are as valid today as when they were written in early 2002.

1. The recruitment and retention of mathematics teachers is a matter for very serious concern. Radical and sustained measures over many years are required following an analysis of the underlying causes of this very real crisis facing mathematics.

No matter what form proposals for reforming mathematical education take, effective implementation will only be possible if there is a substantial increase in the number of mathematics teachers with sufficient understanding of the subject and the enthusiasm and skill to teach it well. Without progress on this issue, real improvements in standards simply cannot be achieved.

2. The quality of teaching and learning of mathematics needs to be greatly improved. The content of the mathematics curriculum is broadly acceptable and does not require substantial change. The problem is not what is taught, but how it is taught, or, much more to the point, what is learnt.

A period of curricular stability is needed to allow real progress in improving the quality of teaching and learning by reducing the pressures on teachers so that they have time to think and plan and engage in sustained professional development. This would help to create the conditions which are necessary for success in easing recruitment and retention problems.

3. The current system of assessment and all the accompanying targets and league tables are having substantial ill effects on the teaching and learning of mathematics. A radical shift away from the current dominance of tests, examinations, targets and league tables is essential if standards in mathematics are to be improved.

The excessive emphasis on tests and examinations has the very serious effect of skewing all classroom activity towards the short term goal of maximising test results. Important aspects of mathematical learning that are hard to assess become optional in the eyes of both students and teachers. A substantial reduction in statutory

<sup>21</sup> *Making Mathematics Count: the Report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education*, February 2004. The report can be downloaded from [www.mathsinquiry.org.uk](http://www.mathsinquiry.org.uk).

testing is necessary if the quality of teaching and learning is to be improved and would contribute greatly to creating an environment in which mathematics teaching is a more congenial task.

The measure of our success is the extent to which mathematics lessons that stimulate interest and boost confidence become the common experience of all students, so that they are able to acquire knowledge and skills with understanding and can apply what they have learnt to a wide variety of challenging situations.

Prior to the publication of the report mathematics had experienced a serious setback when there was a disastrous decline in the number of candidates taking A level as a result of the changes that followed from Curriculum 2000. Whilst there have been modest improvements in numbers since there is, so far, little sign of a rapid return to the numbers prior to those changes which had already been in decline over at least the previous ten years. Smith proposed that groups be set up to consider “pathways” for post-14 mathematics, but other aspects of government reform are hastening change so that the potential good work that had been set in train is being undermined by further piecemeal changes that are not part of a coherent strategy.

### ATTRACTING MATHEMATICS TEACHERS

There is a serious and long standing shortage of secondary school mathematics teachers which includes a significant hidden shortage caused by the employment of many teachers with weak subject knowledge and inadequate training in teaching the subject. It is difficult to quantify these shortages because of the lack of good data, but a recent report from NFER<sup>22</sup> has noted that 24% of those teaching mathematics are non-specialists.

The problem is further exacerbated by the difficulty in retaining good mathematics teachers in the profession. A small scale research project has been set up by The Mathematical Association and funded by the Gatsby Foundation. Its report *Career Patterns of Secondary Mathematics Teachers*<sup>23</sup> has just been published. It draws attention to the important characteristic of mathematics teachers whose major source of career satisfaction is linked to their love of the subject and their wish to communicate that enthusiasm. Disillusionment sets in when the demands of the job make it impossible to sustain that enthusiasm. Many factors influence this, but those concerned with pupil behaviour, workload leading to lack of time and the pressures created by the assessment and accountability systems and by constant changes were commonly mentioned by the teachers and former teachers who contributed to the research. Supportive schools and departments and opportunities for professional development contribute significantly to career satisfaction, but the relentless pressures clearly take their toll on morale, health and the opportunity to lead a normal life.

There is an urgency about tackling the issue of retention, which could begin by acknowledging and then acting upon the fact that many aspects of government policies exacerbate the problems. Many of the difficulties that lead to poor retention also contribute to the problem of recruiting sufficient people into the profession.

### TEACHING MATHEMATICS

There is a remarkably wide consensus about the content of the mathematics curriculum at all levels, but much less agreement about how it should be taught. The National Secondary Strategy has had a variable impact: whilst it provides a structure and a range of ideas that have helped many teachers, it is seen by others as very prescriptive and that is unhelpful in getting the best out of thoughtful and creative teachers.

Moreover many teachers feel seriously constrained by a system that is increasingly controlled from the centre and dominated by the assessment and accountability system, which encourages a narrow “teaching to the test” which focuses exclusively on rehearsing skills and solving standard problems. This compromises the enthusiasm of both teachers and students, fails to develop students’ ability to think independently and detracts from their enjoyment of mathematics, which in turn leads to fewer students wishing to take the subject beyond year 11 and the next generation of parents conveying their distaste for mathematics to their children.

Much more needs to be done to give teachers frequent opportunities to renew their enthusiasm by reflecting on mathematics and the problems of teaching it effectively. Whilst much rhetoric focuses on the value of teachers working together as a team and engaging in professional development, there is little sign of resources being made available on a sufficient scale so that teachers have the time to engage with these valuable activities throughout their careers. The National Centre for Excellence in Teaching Mathematics (NCETM) is an immensely valuable initiative, but its activities will make little impact unless teachers are given adequate time to engage with what it has to offer.

<sup>22</sup> National Foundation for Educational Research (NFER) *Mathematics and Science in Secondary Schools: the Deployment of Teachers and Support Staff to deliver the Curriculum*, January 2006. The report can be downloaded from [www.dfes.gov.uk/research](http://www.dfes.gov.uk/research).

<sup>23</sup> Smart, Teresa and Tickly, Clare *Career Patterns of Secondary Mathematics Teachers*, The Mathematical Association, June 2006.

## SCHOOLS

The issues highlighted in the earlier sections are more critical than buildings and resources although many mathematics teachers are pleased to acknowledge that they have benefited greatly from the expenditure on buildings and ICT resources in recent years. However, there is an urgent need to reduce class sizes. This issue is critical to teacher's morale and the difficulties they commonly face in creating a classroom ethos where learning can take priority over wrestling with the problems of pupils' attitudes and behaviour.

Good teachers are the key to raising standards and improving attitudes towards mathematics. We need government policies that create the conditions in which all teachers feel valued and where they feel able to pursue the difficult task of teaching mathematics free from excessive interference and pressure and, above all, with the time to do the job well.

*June 2006*

### **Memorandum by the National Advisers and Inspectors Group for Science (NAIGS)**

National Advisers and Inspectors Group for Science (NAIGS) is a specialist interest group of the Association for Science Education (ASE), and has approximately 400 members, mainly local authority adviser/inspectors and Secondary National Strategy science consultants and directors, but also advisory teachers, independent inspectors and consultants and ASTs. All these members work to support school improvement, particularly in science, and work frequently in schools, providing advice, auditing provision, inspecting etc.

This response has been prepared via invitations to members to provide evidence. A draft of this document was circulated to members of NAIGS National Committee for comment, and to share in their regions as they saw fit. In addition, small scale surveys have been conducted in recent years by NAIGS members, and the findings have been used to support the commentary below.

#### **1. THE CURRENT SITUATION**

##### *1.1 The numbers of teachers in physics, biology, chemistry and mathematics, including the numbers teaching outside their specialism*

In our experience, in most schools in England teachers will teach two sciences at KS4, but three in KS3, particularly in Y7. The issue here, however, is more complex than solely the match of subject specialist to subject being taught. It's much more about good teaching. In many schools, for instance, those where pupil behaviour is an issue, it is better for pupils to have continuity of one good science teacher, rather than a weekly dose, say, of each of three different teachers. Many pupils of lower ability and with special educational needs also benefit from this approach. In the context of both these considerations and the shortage of supply of physicists, for example, in the short term it is much better to equip the current workforce with the skills to teach outside their own area, rather than to try to plug the gaps with a "quick fix" recruitment initiative. A long term strategy for recruitment (and retention) of science teachers, and physicists in particular, should be developed, but it should be acknowledged that this would take several years to impact fully. A further consideration in training existing teachers is this: who should teach the teachers to teach outside their specialisms? A boring high-level physicist teaching a teacher won't work. Far better for physics teachers with known good pedagogy to teach the other teachers. Identifying these people is possible via local authority advisers and Secondary Strategy Consultants. Then the challenge is getting them out of school.

##### *Proposal*

Increase collaboration between current CPD providers to identify and further develop existing good provision. Ensure CPD is of high quality in terms of subject knowledge development and pedagogy and is delivered in an accessible and stimulating way.

##### *1.2 Regional variations in the supply of science teachers*

There are variations across regions—for instance, particularly in urban areas, schools often have to advertise more than once. This is particularly so for Head of Department posts, and in some LAs, work is being carried out to support Heads of Department through coaching and "buddying" to aid retention. In some areas there are large numbers of overseas trained teachers being employed. This raises issues for local authorities in terms of CPD, many of these teachers have insufficient knowledge of teaching science through practical and investigative activity, and there are associated concerns with regard to Health and Safety.

*Proposal*

Research and map recruitment and retention of science teachers. Introduce support for those geographical areas most in need.

1.3 *The retention levels for science teachers*

Many urban schools have difficulty retaining science teachers. Most who leave do not leave for other professions, but to work in “nicer” schools. Many young teachers “cut their teeth” in tough schools, and then move to schools perceived as easier.

*Proposal*

As above, plus financial and other incentives to retain teachers in “difficult” schools.

## 2. ATTRACTING SCIENCE TEACHERS

2.1 *The incentives that exist to attract new graduates and those from other professions*

In the context of tuition fees, student loans etc, the current “golden hellos” are not big enough to attract science graduates who could be earning lots more in professions other than teaching.

*Proposal*

Write off student loans and debts up to an agreed sum for teachers who stay in the profession for a certain number of years.

2.2 *Other measures that could be taken to increase teacher numbers*

The impact of current strategies to improve science teaching in schools needs time to be felt. In addition, the stress on teachers from such things as challenging pupil behaviour, major changes to the curriculum etc impacts on retention to the profession.

*Proposal*

As above, plus introduce incentives for teachers who stay in the profession eg guaranteed CPD, sabbaticals, secondments, industry placements.

*Proposal*

Introduce changes to the curriculum gradually, in a planned way, with appropriate support materials and funding, rather than imposing changes on teachers all at once, and without adequate support.

2.3 *The effectiveness of teacher training in science subjects*

In some areas, NQTs are viewed to have weak subject knowledge in key scientific concepts. This is not just isolated in physics. Whilst the Secondary Strategy has tried in part to address this, usually only one person from a department can attend training, and it is often difficult to find adequate dissemination time back in school. There are ongoing basic subject knowledge needs of teachers which are difficult to meet. This also applies to primary teachers, where even less CPD is available.

*Proposal*

Create an on-line diagnostic tool for teachers which helps them identify their own knowledge gaps and misconceptions, and associated programmes (CPD, and on-line) to address these.

*Proposal*

Reinstate provision of 10 and 20 day funded courses for primary teachers.

## 3. TEACHING SCIENCE

3.1 *The adequacy of professional support for science teachers*

This varies across the country. In many regions, prior to the establishment of Science Learning Centres, there was (and continues to be) much existing good practice, both in local authorities and via the Secondary Strategy, ASE and Learned Institutions, for example.

In addition, due to the lack of good supply teachers for science and the availability of sufficient funds, in many areas, headteachers are reluctant to allow teachers out of school to attend CPD.

*Proposal*

Ensure geographical coverage of opportunity for teachers, by building on relationships between local authorities, science learning centres and other providers and identify and plug the gaps.

*Proposal*

Develop a system which includes incentives for schools to ensure that teachers access CPD, eg by accreditation of CPD matched to school and personal need.

*Proposal*

Offer teachers payment to attend CPD in school holidays and other times beyond the 1,265 hours directed time.

### 3.2 *The effect of changes in the curriculum on attracting/retaining science teachers*

Changes to the curriculum eg more emphasis on current scientific developments, How Science Works etc will impact on teacher morale, positively in the long run. However, this again will take time. To change GCSEs almost concurrently with post 16 qualifications and KS3 puts a huge strain on teachers. Any changes should be introduced stepwise, and adequate time for embedding of new ideas must be ensured before more changes are made. It's the scale of change which wears teachers down, not the stepwise introduction of up to date material and pedagogy.

*Proposal*

Introduce changes to the curriculum gradually, in a planned way, with appropriate support materials and funding, rather than imposing changes on teachers all at once, and without adequate support.

### 3.3 *The impact of existing schemes designed to help generate enthusiasm in young people for science subjects*

There is no doubt that current STEM activity is of benefit to pupils, however, this needs to be made more coherent, so schools know what's available, and initiatives are used to the maximum effect.

The effect of the Secondary Strategy in making science lessons more relevant to pupils should not be underestimated, and the continuation of the current method of consultants working with teachers is central to this.

Initiatives such as ASE's "UPD8" provide wonderful resources for schools, however, without sufficient funding to make these (and related training) free to all schools, their impact is not as great as it could be.

The testing regime for 11 year olds (including science) has contributed to the narrowness of the curriculum in years 5 and 6 in less well-managed schools, and it is possible that pupils are becoming "turned off" from science in Y6 in particular. Research has also identified a deterioration in attitudes to science during KS3, and we believe this is also partly a result of preparation for tests. This should be further researched, and the method of assessment for 11 and 14 year olds should be reviewed.

*Proposal*

Look into funding appropriate initiatives such as UPD8.

*Proposal*

Review assessment regimes at KS2 AND 3. Consider the introduction of schemes which rely more on teacher assessment, and assessment for learning.

### 3.4 *The role of the practical in teaching science*

"The Practical" is not a term which lies easily with modern science teaching. Whilst the assessment at KS3, for example, in England is weighted 25% scientific enquiry to 75% knowledge and understanding, many teachers use practical activity to enable pupils to better understand science concepts, because this is both motivating for pupils, and also well matched to many pupils' preferred learning styles. Much current science teaching and learning is through scientific enquiry, in which pupils develop their skills of finding the best ways to answer scientific questions. This is much broader than "The Practical", and good science teaching involves pupils in active learning (including practical work) for much more than 25% of the time.

The RSC/CLEAPSS survey into what practical activities teachers think are banned needs further dissemination, to increase the range of exciting and motivating activities which are carried out in schools.

*Proposal*

Continue to disseminate best practice in the teaching of scientific enquiry and “How Science Works” through the secondary strategy.

*Proposal*

Audit current support for primary teachers and consider how to further disseminate best practice.

*Proposal*

Further disseminate key findings of “Surely that’s Banned?”

#### 4. SCHOOLS

##### 4.1 *Variations between schools in the teaching of science, including specialist schools, academies and Community Technology Colleges; procedures for exchange of best practice*

Exchange of best practice is facilitated through existing networks—Secondary Strategy networks eg heads of department, LA networks eg NQT groups, KS2/3 transition groups, and many of these work very well. We have little evidence to suggest that the teaching of science is better in specialist schools, and the use of Specialist Schools and ASTs etc is an area which could be further developed. Part of the problem for headteachers is this—if you’ve got a really good teacher, you don’t want them out of school one day a week! The role of the LA is crucial in identifying best practice. Whilst SLCs can use existing known good INSET providers, they do not have the capacity to search these people out. With the virtual demise of subject inspection, local knowledge will become the main source of finding the best practice.

*Proposal*

Reconsider the role of subject inspection in the gathering of best practice.

*Proposal*

Ensure that existing networks are used to best effect, and that guidance for the roles of specialist schools and ASTs in working outside their own environments are followed.

##### 4.2 *The condition of school labs, and the provision and use of lab technicians and teaching assistants*

The findings of the CLEAPSS/RSC report “Laboratories, Resources and Budgets” 2004 are still very relevant, with little additional spending having impacted on science laboratories. To bring laboratory provision in line with current teaching and learning methodology, a massive input of cash would be needed. In NAIGS surveys, most schools have reported insufficient access to ICT equipment, particularly within the science departments (as opposed to school ICT suites). Although the use of laptops, data-projectors and interactive whiteboards in science is increasing, the provision is patchy at best, and is dependent upon individual schools’ policies, and often on LA support.

The use of technicians and teaching assistants varies hugely between schools. In the worst cases, technicians, for example, are untrained, work in isolation and are stretched to the limit of their capacity. In the best cases, a school has a team of technicians, led by a senior technician, who is both well qualified and experienced. In some of these best cases, a proportion of the technicians work year round (although our data and observations suggest that this is unusual), and all have access to good quality CPD, such as the NVQs offered by the ASE and other providers. However, there is a great deal of work to be done to ensure that best practice is followed in many schools. Adequate backing needs to be given to schemes such as the ASE’s “techcen”, and its Career Structure for Science Technicians. Whilst this structure has been developed in conjunction with organisations such as The Royal Society, CLEAPSS, teaching (and other) trade unions and learned institutions, if it has no standing in terms of explicit government (DfES) support, it is unlikely to impact on technicians in many schools.

Increasingly, teaching assistants are attached to departments, rather than pupils, and are deployed in a variety of ways, including providing cover for absent teachers. In science there are clear health and safety and training implications where teaching assistants are asked to carry out practical activities with classes. This also applies to technicians, many of whom carry out demonstrations on a regular basis, for example.

*Proposal*

Audit the sufficiency, suitability and condition of school laboratories and allocate funding to schools in most need.

*Proposal*

Introduce national career structure for science technicians, and access to appropriate CPD, both for technicians and teaching assistants, building on existing provision.

June 2006

**Memorandum by the National Endowment for Science, Technology and the Arts (NESTA)****1. INTRODUCTION AND SUMMARY**

*Why is NESTA responding and who does it represent?*

1. NESTA, the National Endowment for Science, Technology and the Arts, is working to transform the UK's capacity for innovation. We invest in all stages of the innovation process, backing new ideas and funding new ventures that stimulate entrepreneurship.
2. We act as a catalyst for UK innovation. Our partnerships and networks broker ideas across sectors, accelerating the process of innovation. Our pioneering models of investment are being adopted by organisations throughout the UK. Our strong evidence base helps to influence policy.
3. Underpinning our work is the fundamental view that successful innovation fuels long-term economic and social progress in the UK. It's an essential ingredient of our competitive edge in the global marketplace.
4. NESTA published a research report in November 2005, *Encouraging experimentation and investigation in science learning*, which highlights the UK's need for more "real science" in its schools and classrooms. NESTA has invested in and supported a wide range of innovative projects relating to science enquiry learning. The research also highlights some real concerns and there are some alarming findings: too often science is being taught as "a body of facts", rather than being shown as both relevant to daily life and the glorious exploration of the unknown through practical experimentation.
5. In response to the Committee's inquiry, we would like to highlight the relevant key findings from this research, focusing on our recommendations to see science enquiry at the core of science education in the UK.

*Science enquiry learning and its importance to school science in the UK*

6. Science enquiry involves one or more of the following: raising questions and hypotheses; testing these hypotheses through practical investigations; revising hypotheses based on observations and the interpretation of data; and presenting the findings to others. This can support understanding and awareness of the methods of science, especially science enquiry skills (forming hypotheses, planning experiments, interpreting data, etc.); science enquiry often involves what is commonly referred to as "practical work", that is, the observation and/or manipulation of objects, material or phenomena under investigation.
7. Engagement in practical science experiments involves and motivates learners, and, most importantly, encourages school children to consider taking this interest to undergraduate level. NESTA's projects and those supported by other organisations suggest that science enquiry learning could play an important role in reversing the apparent decline in young people's interest and engagement in school science. Alongside the research, a NESTA commissioned ICM poll found that science teachers had little doubt about the value of science enquiry learning, but had many misgivings about allowing pupils the chance to undertake practical experiments because of health and safety fears and a more general lack of time and resource. The poll, answered by 500 secondary school teachers across the UK, found that 84% considered science enquiry learning to be very important, with 87% agreeing that it can have a significant impact on pupil's performance. An astonishing 87% also said that they had at least once prevented their students from undertaking practical work because they believed current health and safety regulations prohibit them from doing so. A survey commissioned by the Royal Society of Chemistry has echoed these fears.
8. The UK Government has clearly identified scientific research and development as a key driver of productivity and innovation; its ambition is for the UK to maintain and reinforce a reputation not only for outstanding scientific and technological discovery and invention, but also as a world leader for turning knowledge into new products, processes and services.

### *Our Key Recommendations*

9. Science enquiry learning needs to be at the core of science education in the UK. Where it is currently weak or under threat it should be encouraged and enhanced, especially through the development of innovative approaches. Collectively, we need to harness the potential of science enquiry to engage and motivate learners and to counter the misleading impressions of science that can be generated by an over-reliance on more “traditional” forms of learning. However, at the moment, even though there are numerous innovative projects in science enquiry which aim to do just this, too few are able to demonstrate that their practices have been adopted more widely within the system.

10. More generally, all those involved in the education systems of the UK nations—from national policymakers and agencies, to local authorities and teachers—need to consider more systematically the nature of the barriers and enablers to the transfer and adoption of innovations in learning within the education system, and develop policies and resources that will encourage and support the dissemination and testing of innovations.

### *Response outline*

11. This response highlights some of the key findings made in our report, *Real Science—encouraging experimentation and investigation in school science learning*, published in November 2005: as well as our findings since the publication of the report.

- Why is science enquiry learning important?
- Barriers to science enquiry learning.
- How to strengthen science education in the UK through science enquiry learning.

12. For each of the above, this response discusses the issue, its relevance and provides specific recommendations.

## 2. WHY IS SCIENCE ENQUIRY LEARNING IMPORTANT?

13. The Treasury’s *Science and Innovation Investment Framework 2004–2014* clearly identifies scientific research and development as a key driver of productivity and innovation. The UK also has an extremely high reputation for outstanding scientific and technological discovery and invention but also as a world leader for turning knowledge into new products, processes and services. The UK’s science base drives a number of key outputs including new knowledge, new methodologies, and new networks and skilled people amongst many examples, which have all contributed to our wealth, education health, environment and culture.

14. These ambitions require the nurturing of a future generation of highly-skilled science researchers and high-quality school teachers. There are many issues that will determine the future supply of research scientists and science teachers, including pay and retention, and facilities and funding. However, both are likely to be threatened unless science as taught in school classrooms interests and enthralls learners to the extent that more of them consider further study and career options in science.

15. Science is an important area of human endeavour, and learning about science should be part of a high quality education for all. This has practical implications: a strong scientific and technological research base could be reinforced by an informed public understanding of scientific issues, especially potentially controversial issues. This is because higher levels of public scientific literacy and engagement with emerging areas of science could reduce the risk that innovative science and technology is stymied by unnecessarily uninformed or polarised opinion. Science enquiry is a way of investigating the world. Innovation and enterprise depends on these investigative and questioning capabilities. Even non-science innovation relies on skills taught in schools as science enquiry.

### *Recommendations*

16. Those involved in the education systems need to recognise the importance of science learning for all students and also recognise the capacity of existing professionals in system to address these issues.

17. It is also important that action is taken to allow/promote/empower education professionals to put science enquiry at the centre of curriculum and of learning experiences.



18. UK policymakers recognise that unless science enquiry learning as practised in schools is enhanced and extended there are likely to be negative consequences for scientific research and public scientific literacy in the UK.

19. DFES should promote more effectively the opportunities for science enquiry learning that already exist within the established national curricula.

### 3. BARRIERS TO SCIENCE ENQUIRY LEARNING

20. The survey of UK science teachers carried out alongside the NESTA report indicates a number of barriers to science enquiry learning in the UK. A lack of time was cited by 64% of teachers, resources by 34%, equipment and space by 31% and only 17% of teachers thought that their national curriculum allows a lot of scope for practical experimental work. In England according to Ofsted's report on primary science—science is taught in relatively short afternoon sessions of typically 60–75 minutes thus constraining investigative activity. The situation is similar for Scotland, Northern Ireland and Wales. There is also some confusion about the status of current health and safety regulations with an astonishing 87% claiming that they had at least once prevented their students from undertaking practical work because they believed current health and safety regulations prohibit them from doing so. A survey commissioned by the Royal Society of Chemistry has echoed these findings.

#### *Recommendations*

21. UK policymakers, teachers and schools should promote the opportunity for science enquiry learning.

22. UK policymakers should challenge the misapprehensions that may exist amongst teachers and schools around risk, health and safety, and potential litigation relating to the practical experimental aspects of science enquiry learning.

### 4. HOW TO STRENGTHEN SCIENCE EDUCATION IN THE UK THROUGH SCIENCE ENQUIRY LEARNING

23. Science enquiry learning needs to be at the heart of science education. The available evidence base suggests that it could play an important role in reversing the apparent decline in young people's interest and engagement in school science, and the potentially serious consequences of this for the UK's science research base and general science literacy. This is because science enquiry can help learners to understand scientific processes as well as science content. It allows science education to become something that learners participate in, rather than something they are subject to. It represents not only a potentially effective strategy for the teaching and learning of science: it can also serve to model aspects of scientific enterprise itself.

24. Such learning is clearly evidence based and there is growing evidence to suggest that increasing the amount of practical, investigative work can have a marked positive effect on learners' enjoyment of science. In addition, science enquiry can encourage and support a wider and more critical engagement with topics of current scientific interest or controversy. This is important as "real world" engagement can help improve motivation of students. A recent systematic review of "content-based" approaches carried out by the EPPI Centre suggests that these approaches can encourage significantly more positive attitudes to science learning than traditional methods. This is also confirmed by Ofsted's primary science report for England which states that teaching remains more effective where students are actively involved in thinking through and carrying out science enquiry. Teachers also support the significance of science enquiry. A nationwide survey commissioned by NESTA shows that the overwhelming majority of science teachers (84%) think that science enquiry is very important and that 83% believe that science enquiry can have a significant impact on the attainment of their students and 85% on the development of problem-solving skills.

#### *Recommendations*

25. All those involved in the education systems of the UK nations—from policymakers and agencies to local authorities and teachers—need to consider more systematically the nature of the barriers and enablers to the transfer and adoption of innovations in learning within the education system, and develop policies and resources that will encourage and support the dissemination and testing of innovations.

26. Funding and support organisations should create and support more opportunities for partnership and other similar organisations in order to co-ordinate the development of innovations and the transfer of professional knowledge of innovations in science education.

27. Funding and support organisations should help generate a stronger evidence base on the effectiveness of science learning by helping innovative projects to evaluate their outcomes and impacts.
28. Funding and support organisations should support the sustainability of innovative projects by devoting more resources and support to dissemination, transfer and testing after the formal funding periods have ended.
29. Teachers should consider how the opportunities offered by recent and forthcoming curriculum developments in the UK enhance science enquiry activity.
30. Teachers and schools should network with other teachers, schools, subject associations and funding organisations in order to learn about new approaches to science enquiry.
31. Teachers and schools should consider key elements of effective practice in innovative projects in science learning, such as dedicated project managers, making links to topics beyond the traditional science curriculum, making connections with the real lives of learners, and securing the commitment of senior managers within schools.

## 5. CONCLUSION

32. The UK needs more “real science” in its school classrooms. There are worrying signs that our future capacity for innovation could be threatened by the current state of science education in schools. There has been an increasing recognition, shared between practitioners and policymakers across the UK of making science learning more engaging and enjoyable. This has resulted in developments in curriculum design, teacher training and professional development, and in new teaching and learning resources.
33. However, there are still significant problems that remain and too often teaching and learning in science fails to convey what many scientists and others regard as the intellectual discipline and excitement of exploring the unknown, indeed, the “wonder of science”. The continuing imbalance between content and the investigation in school science tends to convey that science is about a fixed body of known facts, and can neglect that it is also about the processes and skills necessary to discover these facts. In effect this gives a misleading and off-putting impression to learners.
34. NESTA’s projects (see Annex A and B) illustrate that science enquiry can engage students to develop their understanding of the processes of science as well as the content of scientific knowledge. By giving students experiences closer to the reality of science, enquiry can encourage the capabilities and confidence to pursue further science learning, even amongst those students who are disaffected and in schools in challenging circumstances. These projects show that investigations and practical experiments can increase motivation, develop thinking skills, support collaborative working, and connect learning about science in the “real world”.
35. Teachers recognise that science enquiry is crucial to science education. In the absence of these opportunities students may fail to develop key skills and aptitudes such as the ability to collate, synthesise and analyse empirical evidence and to ask critical questions. These are important academic skills and they are also life skills.
36. That is why the need for innovation in this area remains. Collectively we need to develop new approaches and methods. Most of the funding and support that is directed at innovations in science enquiry learning comes from charitable trusts rather than government or local authorities, and tends to be developed in universities. This support is valuable, but can be fragmented and lead to a lack of co-ordination. It is also vital for innovations to be sustainable and that teachers and schools are involved from the start.
37. Greater sustainability of innovations would make it more likely that students’ engagement and motivation will be converted into the longer-term gains in attainment. This would provide the evidence necessary to reassure a greater number of teachers and schools that science enquiry activities can be justified within the perceived constraints of their national curricula, assessment systems and available resources.
38. To this end, more support needs to be devoted to the dissemination, transfer and testing of innovations that have been developed. Similarly, more evaluation and monitoring of outcomes and impacts need to be built into these innovations that have been developed. This situation is not unique to science enquiry learning, and so the state of innovation here can be used to raise important questions regarding the opportunities for innovation in science education as whole and indeed the education system more generally.
39. The danger of the present situation is that the UK’s generally high reputation in scientific research will decline—and with it, our future capacity for productivity and innovation, and our ability to develop new solutions to social and environmental issues.

## APPENDICES

### ABOUT NESTA

40. NESTA, the National Endowment for Science, Technology and the Arts is working to transform the UK's capacity for innovation. Innovation drives economic growth and social progress and is an essential ingredient of the UK's competitive edge. Our programmes do three things: develop the skills, attitudes and collaboration required for innovation; increase the availability of seed finance for early stage ventures; and create the policy framework needed for innovation to flourish.

41. Our integrated approach positions us as a powerful catalyst for innovation in the UK. We're setting up vibrant networks to stimulate the exchange of ideas across disciplines accelerating the process of innovation. Our National Seed Fund is the largest single supplier of early-stage capital in the UK developing the next generation of successful businesses. Our knowledge and experience of how innovation works is transforming policy.

### Annex A

#### NESTA'S SUPPORT FOR INNOVATIONS IN SCIENCE LEARNING

42. NESTA has supported innovative ways of learning that provide models for others to follow, and to enhance an appreciation of science, technology and the arts in people of all ages.

Its main objectives are to:

- Source innovative projects that may help to improve practice and/or policy in key strategic areas of learning.
- Bring together on projects talented individuals and organisations who are committed to exploring and sharing new approaches in the fields of formal and informal education.
- Achieve significant benefits for project participants, be they learners, teachers or educationalists.
- Become a useful resource to policymakers and practitioners on innovation in learning.

43. NESTA has a range of other initiatives in science learning and science communication.

- Famelab is a NESTA initiative with the Cheltenham Science Festival, a nationwide competition to find a generation of talented science communicators who can inspire and excite public imagination.
- Planet Science is an online resource for young people and the adults (especially teachers) who support their learning. It's packed full of resources to inform, inspire and stimulate science learning. It receives 1.5 million visits per year and sends an informal weekly e-newsletter to 16,500 subscribers.  
[http://www.planet-science.com/about\\_sy/index.html](http://www.planet-science.com/about_sy/index.html)
- Science Year was a £1 million DfES initiative, delivered by NESTA in 2001–02, to raise the profile of science among young people through a range of ground-breaking activities. Highlights included two mass participation experiments and digital resources for primary and secondary teachers. DfES considered Science Year to be so successful that it was extended for a further year, under the title "Planet Science".
- Crucible is a year-long programme of residential events for up to 30 researchers across science, technology, engineering and medicine. The programme is designed to enhance the creativity and interdisciplinary of post-doctoral researchers by holding workshops on topics as diverse as politics, ethics and globalisation.
- NESTA Futurelab brings together creative, technical and educational communities in programmes of practical experimentation in order to pioneer ways of using new technologies to transform the learning experience. As a "blue-skies" research facility and creative incubator, NESTA Futurlab provides research and development support to those with new ideas for compelling interactive learning resources.

Attracting science teachers: New graduates

Teach First

<http://www.nesta.org.uk/ourawardees/profiles/4169/index.html>

Teaching science: Professional support:

Digital Science

<http://www.nesta.org.uk/ourawardees/profiles/4767/index.html>

Creative Science Teaching Labs

[http://www.nesta.org.uk/ourawardees/profiles/2565/03\\_whatsnew.html](http://www.nesta.org.uk/ourawardees/profiles/2565/03_whatsnew.html)

Teaching science: Enthusiasm in young people:

Planet Science

[www.planet-science.com](http://www.planet-science.com)

Teaching science: Practicals

Making Chemistry Practical, Sheffield University (early stage)—no link available

Films for Learning

<http://www.nesta.org.uk/ourawardees/profiles/5324/index.html>

Schools: Exchange of best practice

National Collaborative (draft evaluation available from Catherine Feeley)

Schools: Condition of School Labs

Planet Science Lab design software

<http://www.planet-science.com/sciteach/index.html?page=/sciteach/labdes/index.html>

Schools: Links between schools and others

Planet Science Outreach

<http://www.nesta.org.uk/mediaroom/newsreleases/4464/index.html>

Open University/Bristol University (early stage)—no link available

Engineering Education Scheme Wales—no link available

Big Screen Science—no link available

Einstein Year

<http://www.nesta.org.uk/ourawardees/profiles/4858/index.html>

[http://www.nesta.org.uk/ourawardees/profiles/4858/03\\_whatsnew.html](http://www.nesta.org.uk/ourawardees/profiles/4858/03_whatsnew.html)

### **Memorandum by the National Institute for Medical Research**

#### INTERACTIONS BETWEEN NATIONAL INSTITUTE FOR MEDICAL RESEARCH AND SCHOOLS

NIMR is embedded in a suburb with many good schools and a large professional population. Our efforts are directed at Science students through the biology content although the importance of chemistry and some areas of physics is implicit in everything we do. We are aware the Inquiry is focussed on recruitment to A level courses. We have no direct influence on recruitment to AS courses in Year 11; our activities are focussed on Year 12 students who will be deciding whether they wish to continue into the A2 part of the course and which courses to pursue at university.

#### *Research Summer School*

This is an intense experience for a small group of students drawn from as many local schools as possible. The idea is to give able students the opportunity to experience science research. The Nuffield Foundation finances the scheme by awarding bursaries to each student. By promoting the scheme effectively in our local schools, we are now confident that able students can see this as a useful step towards a science-based career in biomedical research (and not merely to a place in medical school). This year we selected 17 students from 12 schools, from about 40 candidates to work on projects provided by our young research staff in interesting subject areas. Our staff are now extremely supportive of the scheme; they have discovered that the time is well spent by the students and that 17–18 year olds can make useful contributions even though they are expected to do work far in advance of anything they have attempted previously. Each student produces a poster and report of their work, for events organised by the Nuffield Foundation. However we believe the really important impact is felt

in schools where this material is presented. In our experience, teachers find these impressive and report that they are an inspiring example for subsequent generations of science students. Although the numbers involved are small, their effect is quite far reaching within a school.

*Researchers in Residence/Science and Engineering Ambassadors (SETNET.org)*

A number of schemes exist that recruit young research scientists to go into schools to participate in teaching. The schemes require the visitors to participate in teaching at school for one afternoon a week over one term. Our representatives seem to enjoy the opportunity to be a little more extrovert than usual and the schools welcome their contribution. Teachers suggest they run “revision lessons” for examination classes, to bring some sparkle to a fraught moment of the school year. They can also provide incisive lessons for the routine curriculum of the Sixth Form and lower school, drawing on topics they know intimately. The scheme is still in its infancy but NIMR staff have worked in this capacity in at least six schools in the last year. Not all schools are aware of the merits of the scheme and they are unlikely to have any difficulty in recruiting “Researchers in Residence” if they contact appropriate places. A small element of coercion to “specialist science schools” might be a useful initiative that would encourage them to use this facility more. We shall certainly promote the scheme to all the schools on our mailing list (about 80) in our next round of publicity. The scheme is also very successful in overcoming the stupid stereotypes of scientists that children pick up at primary school (see pictures).

*Annual Schools Days*

The scheme, targeted at potential science or medical students in Year 12, is valued by local schools as a forum for learning about and discussing biomedical topics, careers and ethical issues. About 40 local schools attend the event, in a few cases every year and others more sporadically. Local “specialist science status schools” cite their visits to NIMR as an enrichment activity, in their submission to the DfES.

*Human Biology Essay Competition*

The idea that a 16–17 year old might want to enter an essay competition may seem implausible but we are now in the fourth year of the competition and have had 80 entries from 12 schools. At a time when science students rarely write an extended essay before they go to university, we are challenging schools to be more ambitious for their brightest students. The better teachers know this is a good idea and some students see that getting some practice at assembling a well reasoned argument is a useful skill.

*Communication with Schools*

The rapid turnover of staff in school and intense pressures on teachers makes links with schools exceedingly fragile. However, once we have a stable relationship with a school they recognise we have something useful to contribute. We have many staff who would be happy to give a 30 minute talk at a local school on many topics; however for reasons that we do not understand very few invitations reach us and these are mostly from Independent or Grammar Schools. A website is available (<http://www.biology4all.com/>) through which schools can find speakers anywhere in the UK. NIMR is constructing a similar facility on our own website. One difficulty might be a perception that talks will be too obscure or at too high a level. The only way to overcome this is for schools to emphasise their requirements. Scientists would do well to adopt some of the techniques of school teachers to bridge the gap; younger scientists generally understand this.

**KEY OBSERVATIONS**

- A facility like NIMR can provide “enrichment” of diverse kinds for local schools and can open a channel through which generations of students can see prospects for a career in Biomedical Sciences.
- The main difficulty is the fragile channels of communication between schools and facilities such as NIMR. Teachers should make their requirements of organisations like NIMR and the Researchers in Residence Scheme absolutely clear to avoid disappointments.

- A small element of coercion to “specialist science schools” might be a useful initiative to encourage them to use the large range of expertise we can deploy.
- London Universities ought to provide more places for students to undertake Nuffield Bursaries.

June 2006

### **Memorandum by the National Maritime Museum**

#### **CONTRIBUTION OF MUSEUMS**

Museums and science centres engage with industry, universities, NGOs, consultants, freelance providers, awarding bodies, government departments and teachers as a matter of course in the development of resources and programmes. Positioning themselves as brokers of knowledge and expertise in teaching and learning that has a real opportunity to develop and underpin the skills and understanding of teachers. As a result they are ‘expertise hubs’ within the wider sphere of the science education community, able to provide a range of support for science teachers and other teachers would benefit from increased scientific literacy connected to the arts and humanities. Museums and Science Centres also represent a source of learning and educational expertise in their own right, many including the NMM have links with educational studies departments at universities.

Learning opportunities for school children are often developed climate with resource that enables novel approaches to science teaching that teachers seldom have the time or resources to develop. This is particularly the case in terms of CPD and ITE, for which Museums and Science centres are better able to draw on a far range of expertise, resources and new technologies than any individual schools/independent providers.

#### **MUSEUMS AND THE NEW GCSE CURRICULA**

The new 21st Century Science Curricula, with OCR being exemplars in this area, provide more students with a way into science. In terms of getting people interested, this approach to teaching science will be particularly effective. For Museum programming it provides a wealth of ways in which investigation, dialogue and debate can be used as well as access to collections to explore the research history and philosophy of science, application of science, cultural and social significance, providing opportunities for the provision of more creative learning experiences.

Managing the transition from KS2 to KS3 is equally important. Museums and science centres are in a strong position to provide support in engaging children young and keeping them interested as they move from KS2 to KS3 and throughout their secondary education. The basic 21st Century Science GCSE course has the opportunity to contribute to increasing the scientific literacy of young people, and museums who can engage and entertain the public have an opportunity to play a role in delivering this agenda too.

Delivery of mathematics needs to be connected as strongly as possible to science and this connection needs to be sustained as children move from KS2 to KS3 up to the time they choose their GCSE options—and beyond. Many children are put off taking science further when they are required to engage with equations in a physics lesson. Handling astronomical data, using the National Schools Observatory (NSO) and other programmes that embed software to handle and process data are approaches that will be embedded into the re-launched Education service at the Royal Observatory, Greenwich in 2007.

#### **NMM HEADLINES**

##### *1. Marine Environmental Programming*

This represents a cross-curricular approach to teaching science, citizenship and geography. This activity represents a model of best practice that secondary schools are aiming for but are unable to deliver consistently due to a lack of time and resources, or difficulties in communicating between departments. This approach is bedded firmly into the KS3 national strategy and the Secondary National Strategy. The programme has been developed in consultation with science and citizenship teachers and explores the sustainability and the marine environment. In addition to programmes for schools, funding is being sought to support associated research into public understanding of the subject leading to more effective exhibitions, public programmes, events, conferences and e-learning interpretation for all audiences.

## 2. *GCSE Astronomy*

GCSE astronomy is a good example of current activity. GCSE astronomy supports schools with pupils who want to study the subject but cannot run the course themselves, indicating limited teacher expertise in physics. We currently provide GCSE astronomy tuition for only 90 children every year, but this approach is not something we can grow in a sustainable manner. Instead teacher training, new learning resources, access to experts via new technologies and web based learning materials increase the reach of our science education programme.

Our current GCSE astronomy activity has provided us with access to considerable teaching expertise in the form of our freelance tutors, and will continue to do so. This will allow us to develop approaches that can be grown in a sustainable manner. As such, our current GCSE astronomy offer should be viewed as a precursor to a phase of increasing activity in this area.

NMM will have effective GCSE astronomy CPD for teachers (We will be co-hosting a GCSE astronomy INSET in September), a strong on-site learning offer for GCSE astronomy students (Coming in time for opening in 2007), supporting video conference programmes and effective online and printed resources. Our current activity could be presented as a prelude to this expanding activity.

## 3. *Outreach*

### Video conferencing

The NMM engages approximately 5,500 young people per year in video conferencing sessions. With requests around access to an expert and two-way dialogue, the relationship pre and post a visit is critical. In terms of extending reach, this method certainly delivers effectively. However, classroom support and e-learning materials are essential in this mix.

### Physical outreach

This is not an approach that is sustainable or a strategic way to deliver the diversity of approaches to science at the NMM. However, for targeted project work, this strategy may be used in a targeted and strategic way to build trust, confidence etc.

## 4. *Summer Schools*

Previous summer school activity could be regarded as a pilot for a more strategic, actively marketed summer school programmes for a range of audiences, from G&T to excluded students. The Museum has a track record for National Academy for Gifted and Talented Youth (NAGTY) in the school holidays to run week long programmes. In this area of work, we are more reactive than proactive due to priorities.

## 5. *Barriers to visiting*

There are issues here, including health and safety concerns (and paperwork), travel costs, and internal logistical issues. It is clear that while there are barriers to visiting for secondary school groups, they are not insurmountable. Logistics such as catering for a whole year group are key. From May 2007, with a new Education Centre, this is something that we will be able to provide for astronomy learning in addition to our other work at the Museum. A strong offer, including a full KS1/2/3/4 programme will be in place using direct facilitation, e-learning materials and a state of the art planetarium. It is anticipated that GCSE astronomy and/or 21st Century Science offer would have a significant impact on our uptake, given the limited experience of teachers in delivering these curricula and the increased number of schools trying to offer maximum curriculum choice.

*June 2006*

### **Memorandum by the Science Learning Centres**

#### **SUMMARY**

- The most important factor in inspiring young people to study science is the availability of enthusiastic and well-qualified teachers (paragraphs 4 and 5).

- There is a shortage of teachers with appropriate specialist qualifications, especially in the physical sciences (paragraphs 6 to 9).
- A number of initiatives to improve the supply of science teachers with good subject knowledge are identified (paragraphs 10 to 13).
- Primary science teaching has an important influence on young people's interest and future commitment towards science and should not be overlooked (paragraphs 14 to 15).
- There is now a good supply of high quality continuing professional development (CPD) opportunities for teachers of science, but there are barriers preventing teachers from taking advantage of these opportunities (paragraphs 16 to 21 and 41 to 43).
- The rigid framework of curriculum and assessment in England tends to narrow students' experiences in science (paragraphs 22 to 30).
- Practical work is constrained and limited by shortage of time and by the associated assessment arrangements (paragraphs 31 to 35).
- There is a plethora of support schemes to link school science to the world outside, but these are in need of co-ordination (paragraphs 36 and 37).
- Schools vary widely but the most important characteristic is the quality of a school's staff and the culture towards science in the school (paragraphs 38 to 40).
- Modern and well-equipped laboratories do much to enhance science teaching. The support of well-trained technicians is vital (paragraphs 44 to 47).
- Links to industry and higher education are an effective route to enriching the curriculum and opening students' eyes to science-based careers, but a significant number of schools do not avail themselves of the opportunities (paragraphs 48 to 51).
- High quality careers advice needs to be available to students to show them the many careers available to them if they choose to study science (paragraphs 52 to 54).

#### ORIGIN AND SCOPE OF THIS PAPER

1. This response comes from the network of Science Learning Centres (see Appendix 1). It is informed by the wide-ranging professional expertise of the staff of the Centres and by the views of the many teachers and technicians who visit them. The quotations in this paper are from a consultation of teachers and technicians carried out by the National Science Learning Centre for the specific purpose of this response (see Appendix 2).
2. In line with the specification in the Call for Evidence, this response addresses the decline in the number of A level entries in the sciences and the role that teachers, technicians and teaching methods can play in reversing the decline. In particular, it considers the teaching of physics, chemistry and biology from Key Stage 3 to A level in state-maintained schools and colleges<sup>24</sup>. However, the importance of science teaching in primary schools should not be overlooked (see paragraphs 14 and 15).

#### RELATED WORK

3. This enquiry by the House of Lords comes at a time of exceptional interest and activity in science education. Of particular relevance are:
  - (a) The *Science and Innovation Investment Framework 2004–2014: Next Steps* (March 2006<sup>25</sup>) and the actions identified in it, now being carried through in the DfES by the School Science Review Board.
  - (b) The “STEM Mapping Review” being carried out by Sir Alan Wilson in the DfES, to map and bring co-ordination to the multitude of activity designed to support the teaching of Science-Technology-Engineering-Mathematics (STEM). Sir Alan is due to report in July.
  - (c) Reforms to the science curriculum and its associated assessment, being carried out by the Qualifications and Curriculum Authority (QCA). New science GCSE courses are to be taught in all schools from September<sup>26</sup> and reforms to the Key Stage 3 science curriculum and to science A levels are planned for 2008.<sup>27</sup>

<sup>24</sup> Where this paper refers to the post-16 sector, the term “schools” should be taken to include colleges in the FE sector, and the term “teachers” includes college lecturers.

<sup>25</sup> *Science and Innovation Investment Framework 2004–2014: Next Steps* HM Treasury/DTI/DfES/Department of Health, March 2006.

<sup>26</sup> Details available at [www.qca.org.uk/14944.html](http://www.qca.org.uk/14944.html).

<sup>27</sup> These were foreshadowed in the February 2005 DfES White Paper *14–19 Education and Skills* (Cm 6476).



- (d) The review of science education issues by the Economic and Social Research Council's Teaching and Learning Research Programme (TLRP) and the intention to initiate a significant programme of science education research<sup>28</sup>.

#### SCIENCE TEACHERS

4. The demand by young people for science education beyond the age of 16 and the effect it has on the supply of scientists and engineers is well documented<sup>29</sup>. In analysing the statistics, it is important to disaggregate "science" into its separate subjects because growth in the popularity of some subjects (such as psychology) can mask decline in others (such as physics). Of particular concern is the number of young people coming forward to study the physical sciences at A level and beyond. While the situation in chemistry has stabilised after falling for several years, in physics, numbers taking A level continue to decline. Paradoxically, this decline in interest is occurring at the same time as attainment in science (as measured, for example, by GCSE results) is rising.

5. It is appropriate that the House of Lords inquiry should focus particularly on the role of teachers. Inspired teaching is the key to inspiring young people towards the continued study of science. As a teacher in a school in Cumbria put it: "Enthusiastic, well-informed, skilled communicators who have a passion for their subject are vital". We would add to this the importance of well-trained technicians and teaching assistants to support secondary science teachers, particularly in practical work.

#### *The supply and qualifications of science teachers*

6. In considering the supply and qualifications of science teachers it is again important to disaggregate "science" qualifications into the major specialist subject areas: physics, chemistry and biology. If numbers are aggregated, the healthy supply of biology specialists, for example, can mask the shortage of physics specialists.

7. The current situation concerning the qualification and supply of science teachers has been well documented in the report recently produced for DfES by the National Foundation for Educational Research<sup>30</sup>. Some significant findings arising from this study are:

- (a) Of all teachers of secondary science, 44% are Biology specialists, 25% are Chemistry specialists and 19% are Physics specialists.
- (b) Among 11–16 schools, 25% have no Physics specialists at all.
- (c) Non-specialist teachers are most likely to be found in:
  - the lowest attaining schools;
  - schools serving socio-economically deprived areas; and
  - 11–16 schools.

8. For the first part of secondary schooling, science is usually taught as a single discipline. This makes it easy to forget the importance of the separate scientific disciplines: physics, chemistry and biology—not to mention earth science, psychology and others. In some ways, this does not matter too much—teachers are trained to teach across the sciences to the end of Key Stage 4, and many modern curricula are designed to be taught, in part at least, as an integrated whole. But in other ways, subject specialists are very important. Incomplete understanding and lack of confidence in a subject limits the ability of a teacher to provide deep and inspiring subject knowledge. Schools need a balance of subject specialists, yet recruiting specialists who are also effective teachers is a major challenge for many schools. As a teacher in a girls' school in London put it: "Our big concern at the moment is getting enough good science teachers who are specialists."

9. The problem of shortages in subject specialism can partly be addressed by measures to improve recruitment (paragraphs 10 to 13), though this will take time. Another part of the solution is to provide re-training for non-specialists. Here the initiatives already being taken by the Royal Society of Chemistry and Institute of Physics are important, as is the proposal in the *Science and Innovation Investment Framework 2004–2014: Next Steps* for a Diploma for non-specialists. The Science Learning Centres are in a good position to develop this diploma; furthermore, the network of regional centres can respond effectively to regional variations in the supply of specialist teachers.

<sup>28</sup> *Science education in schools: issues, evidence and proposals*. A commentary by the Teaching and Learning Research Programme (2006). [www.tlrp.org](http://www.tlrp.org).

<sup>29</sup> For example, in *SET for Success: The supply of people with science, technology, engineering and mathematics skills*. The Report of Sir Gareth Roberts' inquiry for HM Treasury (2002).

<sup>30</sup> *Mathematics and Science in Secondary Schools: The deployment of teachers and support staff to deliver the curriculum*. NFER, commissioned by DfES, 2006.

*Recruitment and retention of science teachers*

10. With biology specialists in relatively good supply, the major challenge lies in the recruitment and retention of physics and chemistry specialists. The recruitment measures identified in the “Next Steps” document, and to be taken forward by the Training and Development Agency for Schools (TDA) are a move in the right direction, but ultimately the only effective way of recruiting extra physical scientists may be to pay them more than other teachers—an approach that has proved problematic to implement in practice. But as a teacher from a school in Buckinghamshire put it: “Perhaps the time is coming for teaching to realise that some skills are in short supply and that it is necessary to provide the right incentive in order to recruit, and retain, the staff that are needed and that this incentive might not be universally applicable throughout the profession.”

11. Most secondary teachers enter the profession after taking a postgraduate certificate in education (PGCE). The PGCE has remained largely unchanged for many years, and it may be that the balance between the school-based and university-based components, and between science subject content and pedagogical content, is due for re-examination. The case for some PGCE courses to last for more than a year, in order to enhance subject knowledge, is strong. The enhanced PGCE science programmes piloted by the Gatsby Technical Education Programme may provide useful pointers.

12. Science graduates are in demand in many employment sectors, and good science teachers are difficult to retain as well as to recruit. Rapid turnover of staff, often compounded by recruitment difficulties, have an inevitable effect on the quality of teaching. The problem of staff turnover is worse in some regions (for example, London) than in others. Adding to these difficulties is the shortage of qualified supply staff to provide cover for teachers who are sick, absent or away to receive continuing professional development (CPD). Leaving aside the question of pay, the problem of retention is partly related to working conditions. One way of addressing it is by improving the professional opportunities available for science teachers, particularly the opportunities for CPD through the Science Learning Centres (Appendix 1).

13. Around two-fifths of newly-recruited science teachers leave before their fifth year of teaching<sup>31</sup>. Support for newly-qualified teachers<sup>32</sup> can ameliorate this position, as can systematic CPD, which increases teachers’ sense of ongoing commitment to the profession they have entered. The suggestion from the Teaching and Learning Research Programme<sup>33</sup> that those who remain as full-time science teachers for four or more years should have their students debt written off deserves serious consideration.

*Primary science*

14. The importance of a good foundation of science in primary schools should not be underestimated. The seeds of enthusiasm and passion for science are readily sown in young children. Since the introduction of the National Curriculum for science in the late 1980s, science in primary schools has developed significantly, though it is increasingly at risk of being eclipsed by the greater emphasis placed on literacy and numeracy. The training of primary science teachers to improve both their science subject knowledge and their teaching skills remains a high priority for the Science Learning Centres.

15. However, there is a danger that the strong, and growing, emphasis on testing in both primary and secondary schools will extinguish the early enthusiasm for science that is kindled in primary schools. As a teacher from Cumbria put it: “If an interest in science is triggered in primary school then it is important that the child’s experience of this is enriching and not driven by the perceived need for summative testing”.

## TEACHING SCIENCE

*Professional support for science teachers and technicians*

16. Science teachers have historically benefited from a good infrastructure of professional support. The Association for Science Education (ASE), by far the largest and most active of the subject teaching associations, provides support for teachers of science at all levels. The Institute of Physics and the Royal Society of Chemistry provide subject-specific support. Through their journals, meetings, professional development courses and curriculum initiatives, these professional associations provide rich support. Such support is in contrast to the much more limited professional infrastructure available to “newer” science subjects such as psychology and sports science.

<sup>31</sup> See, for example, the Smithers and Robinson report *Teacher turnover, wastage and destinations*, DfES 2004.

<sup>32</sup> For example, the National Science Learning Centre’s Summer School for Newly-qualified teachers.

<sup>33</sup> *Science education in schools: issues, evidence and proposals*. A commentary by the Teaching and Learning Research Programme (2006). [www.tlrp.org](http://www.tlrp.org).

17. In recent years, the availability of continuing professional development (CPD) has been further increased by the arrival of the DfES-funded Secondary National Strategy (SNS). Working mainly through local authorities (LAs), the SNS has provided centrally-directed initiatives to improve the teaching of science through training of teachers, most notably in Key Stage 3 of the secondary school curriculum.

18. Since the opening of the Science Learning Centres from 2004 onwards, the availability of CPD has become richer still, particularly in the provision of up-to-date knowledge of science subject matter and teaching skills.

19. There is thus a good supply of high quality professional development available to teachers, yet the barriers to their making use of them are considerable. A recent survey of teachers' experiences of CPD<sup>34</sup> found that half of all secondary science teachers in the survey said they had had no subject-specific CPD in the past five years.

20. The significant barriers to teachers' getting the opportunity to attend CPD events include:

- cost;
- the difficulty for schools of getting specialist supply cover;
- the policy in some schools of discouraging external CPD in favour of in-house provision; and
- the absence in some schools of a policy of entitlement to CPD.

There is not yet a pervading culture favouring CPD in schools, and it is sometimes difficult for teachers to get the support of their headteachers to participate in externally-organised CPD. Incentives for teachers to take part in CPD are not yet embedded in the profession—though this may slowly change with the introduction by TDA of the new framework of professional standards for teachers<sup>35</sup>. We support the recommendation of the Teaching and Learning Research Programme report<sup>36</sup> that: "A national structured programme of continuing professional development should be provided as an entitlement for all science teachers in post. The successful completion of stages in this programme should be recognised by incentives such as salary increments and teaching-related sabbatical leave".

21. A systematic and well-understood framework of professional accreditation would incentivise teachers to engage in CPD, in the way that other professionals such as medics and chartered accountants do. The establishment by the ASE of a Chartered Science Teacher scheme is therefore to be welcomed.

#### *The curriculum and assessment*

22. The principal focus of this response is science teachers, but it is impossible to pass over the crucial role of the curriculum and its assessment, which form the medium within which science teachers and students operate, day in day out. England<sup>37</sup> has a powerful combination of a centralised curriculum and an allied assessment system which, when coupled with league tables, leads to what is for many an excessively constrained curriculum and an over-emphasis on tests and preparation for them. Testing dominates the teaching of science at the upper end of primary schools and in secondary schools at all levels. Furthermore, the statutory tests and examinations at ages 11, 14, 16 and 18 often assess a narrow range of skills and factual recall dominates the tests and preparation for them.

23. Modular assessment schemes, which are often used at GCSE and A level, can compartmentalise students' understanding of science. As a teacher in a Sheffield school said: "Teaching to rigid GCSE specs takes some of the spontaneous sidetracking away. Students often don't see science as a whole but as lots of one-off modules which don't link together both within and between subjects".

24. Further narrowing of the science curriculum has come about because of a compliance culture which has developed in some schools, whereby, for example, many teachers believe they are obliged to follow the optional Schemes of Work suggested by the Qualifications and Curriculum Authority.

25. In the quest for ever higher attainment, schools make sophisticated use of test data to identify, and subsequently target, underperforming students and those at the borderlines, whose grades can most readily be improved. While these targeted activities have benefits in trying to ensure an individual approach to each child's needs, such relentless attention to data and test results may at times lead to a narrowing of students' learning experiences.

<sup>34</sup> Wellcome Trust (2006) *Believers, Seekers and Sceptics: what teachers think about continuing professional development*. [www.wellcome.ac.uk/doc\\_WTX027756.html](http://www.wellcome.ac.uk/doc_WTX027756.html).

<sup>35</sup> See [www.tda.gov.uk/teachers/currentconsultations/professionalstandards.aspx](http://www.tda.gov.uk/teachers/currentconsultations/professionalstandards.aspx).

<sup>36</sup> *Science education in schools: issues, evidence and proposals*. A commentary by the Teaching and Learning Research Programme (2006). [www.tlrp.org](http://www.tlrp.org).

<sup>37</sup> These remarks relate to the situation in England: arrangements in Wales and Northern Ireland are somewhat different, and Scotland is radically so.

26. As a result of the emphasis on tests and preparation for them, there is less time for teachers to provide students with the kinds of experiences that research<sup>38</sup> shows they enjoy most in science:
- practical laboratory work that excites interest;
  - discussion of ideas with one another;
  - experiences of science outside the classroom; and
  - seeing the relevance of science to their own lives.
27. The new national curriculum Programme of Study for Key Stage 4 Science, which will be the basis of all science GCSE courses from September 2006, emphasises scientific literacy and the way science affects people's lives. Arising from the influential *Beyond 2000* report<sup>39</sup>, it potentially offers both the content and the learning experiences that students favour. A pilot of this new curriculum, called *Twentyfirstcentury Science*, took place between 2003 and 2005 in about 80 schools and the evidence emerging from the evaluation of the pilot suggests that "clearer links between school science and science as it is encountered out of school lead to greater student interest and involvement."<sup>40</sup> However, it remains to be seen whether these benefits will endure when all schools adopt the new curriculum, of which there will be a number of different versions, when it is universally adopted from September 2006.
28. The narrowing of the curriculum and learning experiences affects students directly, and also affects the morale of teachers by removing from them much of their professional discretion. As a teacher from Cumbria put it: "My colleagues and I frequently comment on what could be done to increase student engagement if we were allowed creative professional freedom in determining a suitable curriculum for the students".
29. A further disincentive to study physical sciences at A level arises from the perception that they are hard. To some extent, this is borne out by statistics: studies at the University of Durham<sup>41</sup> that, for example, A level Physics is one grade harder than A level Sociology. Such perceptions take their toll among students who are acutely aware of the grades they need to get into the universities and courses of their choice. As a teacher in Lancashire put it: ". . . it's the perception (reality?) that science A levels are 'a lot of hard work' compared to other subjects. More needs to be done to sell the relevance of science at A level and reassurance that the extra work is worth it."
30. The planned changes to A level assessment arrangements from 2008, involving a modest reduction in the burden of assessment, may help somewhat, but we believe that more far-reaching changes are needed to the assessment arrangements for curricula at all levels. In particular, we recommend that summative, external assessment should bear less heavily on what goes on in the classroom and laboratory, and that there should be a greater emphasis on the use of assessment to help teachers and students to judge their progress as they go along (so called "assessment for learning"). Taken together, such developments would improve the quality of learning and free time for activities to engage students' interest in science.

### *Practical work*

31. Students enjoy variety, and for effective learning, a range of teaching methods is needed, including group discussion, computer assisted learning, and science outside the classroom. Direct instruction by the teacher will always play an important part, and when it is from an enthusiastic teacher with good subject knowledge, there is nothing like it. Not surprisingly, students do not enjoy taking dictated notes or copying work from books, nor are these methods effective in promoting learning. Yet they are surprisingly common, perhaps because they are seen as a way of making sure all of the syllabus has been covered.
32. Practical work is the essence of science, and there is much evidence that students enjoy good quality practical work and find it stimulating. Yet practical work needs to have a purpose in helping students learn about the processes and content of science. There are two problems preventing teachers doing high quality practical work.
33. First, many teachers complain that, with pressure to get through the syllabus, they cannot find room for much practical work. The second problem is associated with assessment of practical work: under the current arrangements, the national tests at ages 14 and 16 require teachers to assess practical skills, but the highly specific criteria against which this assessment takes place tends to lead to a formulaic approach more akin to

<sup>38</sup> *Pupils' views on the role and value of the science curriculum: a focus group study*. Osborne J and Collins (2001), *International Journal of Science Education* 23, 441–468.

<sup>39</sup> *Beyond 2000: science education for the future*. Millar R and Osborne J (Eds) (1998) King's College, University of London.

<sup>40</sup> *Science education in schools: issues, evidence and proposals*. A commentary by the Teaching and Learning Research Programme (2006). [www.tlrp.org](http://www.tlrp.org).

<sup>41</sup> CEMC, University of Durham.

jumping through hoops than carrying out true scientific enquiry. In the long term, changes to assessment arrangements to encourage a more open-ended practical investigations would be valuable.

34. At the same time, many teachers, especially those whose specialism is not in the subject they are teaching, lack the experience and confidence to carry out the kind of practical work that can stimulate and inspire. Perceived, but often illusory, safety problems can further inhibit teachers from the more innovative class experiments, as well as the teacher demonstrations that can be such a memorable experience for students. CPD for science teachers needs to provide opportunities for them to experience and practice new experiments and demonstrations. Providing these opportunities is a key part of the mission of the Science Learning Centres.

35. Practical experiences not easily conducted within the classroom are provided by science centres, universities and in industry. A small study currently being conducted by At-Bristol and the University of Bristol indicates that these experiences have a strong positive influence on students' A level and university course choices, especially when coupled with exposure to practising scientist and engineer role models. Challenges exist to involve all schools in such experiences.

#### *Support schemes*

36. There is a plethora of schemes, both publicly and privately funded, to help teachers show the relevance of science and mathematics to the outside world, and to help generate enthusiasm for science. These "STEM" schemes have been identified and mapped as part of a review carried out by Sir Alan Wilson, who is due to report by July 2006 and to make recommendations for how the STEM support landscape might be rationalised.

37. The problem for science teachers is that they often feel they do not have time—for the reasons identified above—to take advantage of the STEM schemes. Even if they did have time, such is the complexity of the provision that teachers find it hard to identify what would be most appropriate for their local needs. The intention in Sir Alan Wilson's emerging recommendations is to rationalise provision around a network of regional STEM Support Centres, based in the regional Science Learning Centres and employing a common STEM Support portal. This builds on a pilot scheme for "STEM regional hubs" initiated by Sir Gareth Roberts with the support of the Gatsby Foundation. This is potentially a big step forward, provided it is supported by the necessary resources and willpower needed for its implementation. Crucial to its success will be a local delivery network at sub-regional level that is capable of reaching every school, including those that do not customarily get involved in enrichment activities.

## SCHOOLS

### *Variations between schools*

38. There is much variation between schools, but also much in common. All state-maintained schools<sup>42</sup> must follow the national curriculum and its assessment arrangements, with the constraints that this entails. The crucial variations between schools are in the quality of the science facilities, the existing ethos towards science, and above all the quality and qualifications of its science teachers. The recent survey of science staff<sup>43</sup> indicates that schools in the most socioeconomically deprived areas tend to have the least qualified teachers. This is further compounded in areas like London and Bristol where there are recruitment and retention difficulties. There is evidence<sup>44</sup> that, in Physics at least, the qualifications possessed by teachers is a strong determinant of students' performance.

39. If a school can establish a positive culture towards science, this can have a major influence on students. As a teacher in a Sussex comprehensive school with good uptake of A level science put it: "I think the reason a lot of our students want to carry on to science in the sixth form is because we have highly skilled teachers who engage the students from year 7 onwards. By the end of year 9 we are already talking to them about the future in terms of science courses. In years 10 and 11 we initiate discussions about courses and career options."

40. With such wide variations between schools, schemes to encourage schools to support one another are to be welcomed. These have been stimulated by the Specialist Schools and Academies Trust's (SSAT) policy of encouraging schools with a specialism to support other schools. This has proved highly effective where secondary schools provide support for primary schools, but less easy to achieve between secondary schools.

<sup>42</sup> With the exception of the coming new generation of City Academies.

<sup>43</sup> *Mathematics and Science in Secondary Schools: The deployment of teachers and support staff to deliver the curriculum*. NFER, commissioned by DfES, 2006.

<sup>44</sup> Smithers and Robinson, 2005: *Physics in schools and colleges: teacher deployment and student outcomes*. Gatsby Foundation/University of Buckingham.

41. Professional development activities, such as those of the Science Learning Centres and the ASE, designed to share good practice are also effective. In partnership with Local Authorities, Specialist Science Schools and SETPOINTS, the regional Science Learning Centres have developed effective models of CPD provision that meet the local needs of individual schools and clusters of schools. Studies of effective professional development invariably conclude that the most valued aspect is the opportunity for professionals to share their experiences of common challenges.

42. The policy of some schools to discourage teachers going out of school for CPD (instead, focussing on in-house training) is a concern in this respect. If schools lack subject-specific expertise, for example in physics, they are not in a position to provide training in that subject in-house. Yet there is an increasing trend towards delivery of CPD in this way.

43. Face to face CPD experiences offered through the Science Learning Centres catalyse communities of practice between teachers with similar concerns. The Science Learning Centres web portal provides support for these communities of practice, enabling good practice to be shared and implemented in the classroom.

#### *School laboratories*

44. Modern, well-equipped laboratories are an important part of establishing a positive image for science in a school. As a teacher in a Staffordshire school put it: “The value a school places on science [is] manifested by the quality of its physical resources”. The availability of funding to refurbish laboratories is often referred to as one of the major advantages of becoming a science specialist school under the SSAT. Increased government investment in school laboratories is therefore greatly welcomed, though it will take a long time until it has fed through to all schools.

45. The support of well-trained technicians can make a crucial difference to the job science teachers are able to do. Good technicians can transform the morale of a department by ensuring its smooth running and providing support and guidance for less experienced teachers. Technicians can be the most passionate supporters of science in the school<sup>45</sup>.

46. Yet technicians are usually the poorest-paid members of the department, and until recently the opportunities available to them for CPD and training have been limited. Since their opening, the Science Learning Centres have experienced strong demand for CPD from technicians. The establishment of a well-defined professional framework for technicians is important to the future health of school science, and the initiative of the ASE to establish a Diploma for school laboratory technicians is significant.

47. School science departments need adequate capital funding, not only for laboratories and equipment, but also for textbooks and other learning resources including electronic media. This is particularly important when new curricula, such as the new GCSEs from September 2006, are introduced.

#### *Links for schools with university and industry*

48. Links with universities and industry serve many purposes for school science teachers. Most importantly:

- They keep teachers in touch with the front line of scientific research and the applications of science in industry, helping them find ways to bring interesting and relevant contexts into their teaching.
- They can help students to learn about opportunities for studying science and related subjects in higher education, and for discovering about the many careers open to those who follow such a route.

49. With their strong links to higher education and industry, the Science Learning Centres are in a good position to facilitate such links for schools. For example, all 10 Science Learning Centres have a strong link to one or more universities, and the majority are physically located within a university. Several Science Learning Centres have a regional industry as one of their founding partners. Additional links exist with scientists in science centres and science and natural history museums. Science Learning Centres are thus able to draw on academic and industrial scientists to provide teachers and technicians with up to date information about the frontiers of science and careers available in science.

50. SETNET—the network of consultants working to link schools with industry—is being reconstituted with a regional structure linked to Science Learning Centres, and this reinvigorated network should provide improved opportunities for schools to make contact with local industries. As ever, the challenge will be to reach all schools, especially those that do not normally get involved in such enrichment activities. A technician from a school in Berkshire said: “Enrichment through trips to industry is difficult to arrange because of time

<sup>45</sup> A study carried out at Science Learning Centre East Midlands has provided evidence of the wider impact that CPD for technicians can have on the whole science department.

constraints to deliver the rest of the curriculum . . . seeing science in action in the outside world entuses students and allows them to see where they can go after their studies have finished.”

51. Schemes to bring researchers and industrialists into the classroom—such as Science and Engineering Ambassadors, Researchers in Residence and Undergraduate Ambassadors—can bring up-to-date and relevant science into the classroom and provide good role models. However, once again the challenge is to get the harder-to-reach schools involved. It is also important to ensure that both teachers and ambassadors have appropriate training to enable them to make the most of the rich possibilities.

52. High-quality careers advice and guidance is essential to getting more young people interested in continuing their study of science. As a teacher in Somerset put it: “. . . I think the main reason [for the lack of interest in studying science] is that pupils don’t get the right careers advice. When pupils are choosing post 16 options there needs to be a greater input from industry so pupils can see where taking A level science could lead them. Pupils taking A level science seem to be stuck in the idea that their career path will be as a doctor or a vet.” And a teacher in Greater Manchester: “We are now seeing an increased interest in chemistry thanks to the TV series CSI. Industry could take some tips from the series to market itself at students in an accessible way. If they don’t students are going to be increasingly attracted to media studies and computing as they see their relevance around them every day in the world they live in.”

53. A great deal of work remains to be done to make high-quality careers information available to all students. Action is needed on several fronts, including:

- Making better careers information available to science teachers, who are often the people to whom students and their parents turn first when considering whether to opt for science subjects.
- The development of a universal STEM careers website providing comprehensive and unbiased information to students, teachers and parents about the careers available to those who opt for science. Such a website is under development by a group co-ordinated by the Science Council, and it is important that all interested parties in the STEM community are fully involved in this work.
- Helping all schools to become involved in science activities out of school where their students will come into contact with people who have made their careers in science.

54. The *Science and Innovation Investment Framework 2004–2014: Next Steps* document includes a commitment to work with key stakeholders to develop ways of improving careers awareness, but this commitment needs to be fleshed out with firm proposals for action.

June 2006

## APPENDIX 1

### THE NATIONAL NETWORK OF SCIENCE LEARNING CENTRES

The network of Science Learning Centres is an initiative of the DfES and the Wellcome Trust. Launched in 2003 and in operation from October 2004, the Science Learning Centres were established to provide high quality Continuing Professional Development (CPD) for teachers of science in primary and secondary schools and FE colleges, and school laboratory technicians and teaching assistants. The focus of this CPD is to update both subject knowledge and teaching skills, and so make science teaching more inspirational.

The nine regional centres for England are funded by the DfES until 2008 at a total cost of £26 million. The National Science Learning Centre for the whole of the UK is funded by the Wellcome Trust until 2013 (with a review in 2008) at a total cost of £25 million.

#### LOCATION OF THE CENTRES:

Science Learning Centre London  
 Science Learning Centre South East  
 Science Learning Centre East  
 Science Learning Centre East Midlands  
 Science Learning Centre Yorks & Humber  
 Science Learning Centre North East  
 Science Learning Centre North West  
 Science Learning Centre West Midlands  
 Science Learning Centre South West  
 National Science Learning Centre

Institute of Education  
 University of Southampton  
 University of Hertfordshire  
 University of Leicester  
 Sheffield Hallam University  
 Framwellgate School, Durham  
 Manchester Metropolitan University  
 University of Keele  
 @ Bristol  
 University of York

In particular, the Science Learning Centres provide:

- High quality CPD delivered by experienced teachers, education specialists and scientists from academia and industry.
- Well-found, purpose-built physical environments.
- A bridge between schools and science through their strong links to scientists in partner Higher Education institutions (HEIs) and in industry.
- Direct access to a wide range of educational expertise through their partnerships and their links with HEIs.
- A high-capacity web portal designed to support CPD that is, in addition to its main purpose, providing the platform for web portals for the National Centre for Excellence in Teaching Mathematics and the “STEM regional hubs” initiative.
- Growing experience of delivering contracts for DfES and other government agencies, for example the “Success for All” post-16 initiative.
- A network that is able to act in a co-ordinated way yet is responsive to regional agendas and needs. The Co-ordination committee is chaired by Sir Gareth Roberts.

More details about the Science Learning Centres are on the web portal at [www.sciencelearningcentres.org.uk](http://www.sciencelearningcentres.org.uk)

## APPENDIX 2

### CONSULTATION OF TEACHERS AND TECHNICIANS BY THE NATIONAL SCIENCE LEARNING CENTRE

A discussion forum was set up by the National Science Learning Centre on the Science Learning Centres web portal, initiated by the letter below. The members of the forum are all teachers and technicians who have attended the National Science Learning Centre in the past year. 32 responses were received, some of which are quoted in this paper. The original responses are available on request.

**Posted by John Holman on 26 May 2006 at 12.55**

Dear Colleague,

Science Learning Centres have been asked to give input into the House of Lords Science and Technology Select Committee report about science teaching, so we thought this would be an ideal time to test out our new Teacher Consultation Panel forum, and give you a chance to make a direct contribution to our presentation.

Please feel free to answer any way you like, bullet points, a short sentence or a few words will be fine—I know you are too busy to produce a thesis at such short notice!

The big question they are trying to answer is:

- What are the key factors in getting good recruitment to A level Science?

The Lords are visiting the National Science Learning Centre in mid-June, so we need your feedback by 12 June at the latest. Please post your feedback on the forum or reply to this message using the link below.

Looking forward to reading your post on the forum, and thanks in advance for your help.

Best wishes

John Holman

PS To get you started you might want to think about some of the following, supply of qualified teachers/technicians, retention of teachers/technicians, the curriculum, assessment, professional development, the role of practical work, enrichment activities, the condition of school labs, links between schools and industry etc.

### Memorandum by the Newcastle Science City Initiative

#### ORIGIN AND SCOPE OF THIS PAPER

1. This response comes from Joan Sjovoll, Headteacher, Framwellgate School Durham and Dr Sally Preston, Director, Science Learning Centre North East. Joan Sjovoll has been commissioned by the partners of Newcastle Science City initiative to lead the development of a regional Integrated Science Education Strategy for the North East with Dr. Sally Preston. This response is informed by the wide-ranging consultation and research carried out across the North East Region.



2. In line with the specification in the Call for Evidence, this response addresses the decline in the number of A Level entries in the sciences and the role that teachers and teaching methods can play in reversing the decline. In particular, it considers the teaching of physics, biology and chemistry from Key Stage 3 to A Level in state schools. However, given the research evidence regarding the decline in interest in curriculum science during the primary phase, we have made reference to this in our submission.

#### INTEGRATED SCIENCE EDUCATION STRATEGY FOR THE NORTH EAST

3. Newcastle Science City is providing significant new opportunities to boost the economic and social development of the North East. However, it is important to emphasise that the Newcastle Science City Education Strategy is regional in its scope and impact. Stakeholders across the Region are contributing to, and benefiting from, the programmes. The proposals for Science City envisage education as a central element of the programme. The proposals feature a focus on “the nurturing and attraction of people to work in science and learn science and the widespread promotion of participation and excellence in our schools.”

4. The overall aim of the Integrated Science Education Strategy is to:

“widen participation and increase attainment in science education by all learners, particularly young people with improvements year on year over 10 years”.

5. The strategy will improve attainment throughout primary, secondary and Further Education and widen and increase participation post-16 in both “academic” and “vocational” science. To achieve these aims, there is a need to address the key factors that now constrain participation and attainment. These include:

- Relatively low student interest in/enjoyment of science—this often starts at primary schools as many teachers lack science expertise.
- The current secondary science curriculum (and assessment regime) as it is focused on learning scientific content and this limits the scope for creative and enquiry-based activities.
- A lack of engagement with sustained subject-focused professional development for teachers and lecturers in primary, secondary and Further Education.
- The need for more up-to-date information on career opportunities in science and higher education pathways.

#### THE SUPPLY AND QUALIFICATIONS OF SCIENCE TEACHERS

6. Research undertaken by the Wellcome Trust<sup>46</sup> suggests that, although primary teachers do not need a strong scientific background to teach science, many lack the scientific background knowledge, confidence and training to effectively teach science. The Integrated Science Education Strategy recommends that all teachers of science—both primary and secondary (including Further Education)—in the Region have an entitlement for professional development.

7. In 2002, the Set for Success<sup>47</sup> report highlighted the national teacher recruitment issue for science specialists, with the particular difficulty in recruiting maths, physics, and chemistry specialists. Mirroring this research, research undertaken more recently by NFER on behalf of the DfES<sup>48</sup> into the deployment of maths and science teachers found that, amongst science teachers in secondary schools, there is an imbalance in the representation of school science. 44% had a specialism in biology, 25% in chemistry and 19% in physics. 26% of all 11–16 schools did not have any physics specialists. Evidence collected during the wide-ranging consultation in the Region suggests that schools in the North East reflect similar patterns.

8. In Double Award Science, only two fifths of those teaching chemistry had studied chemistry at degree level or by initial teacher training and only one-third of those teaching the physics element had specialised at degree level or in initial teacher training. Within the North East, there is a particular problem in recruiting physics specialists.

9. Non-specialists are more likely to be teaching the “low ability” groups and groups/courses that do not involve national assessment. They are also found in the lowest attaining schools serving socially and economically deprived areas. Receiving less exposure to specialists can affect pupils’ perception of the sciences and decisions as to whether they should be continued in the longer-term.

<sup>46</sup> Primary Science in the UK: A Scoping Study, Wellcome Trust, April 2005.

<sup>47</sup> Set for Success Report, Final Report of Sir Gareth Robert’s Review, House of Lord’s Committee for Science and Technology, April 2002.

<sup>48</sup> Mathematics and science in secondary schools—the deployment of teachers and support staff to deliver the curriculum, NFER on behalf of DfES, 2005.

10. There is also a lack of continuing professional development of science teachers. A survey undertaken by the Council for Science and Technology<sup>49</sup> concluded that science teachers were not engaged in a subject-related, systematic process of continuous professional development. Teachers generally reported that their opportunities to build on their initial training were very limited and tailed away sharply after the first, induction year of their careers. Since the opening of Science Learning Centre North East in January 2005, there has been an increasing take up of subject-related professional development within the Region.

11. More recent research by the Wellcome Trust published in January 2006<sup>50</sup> found that secondary science teachers were particularly keen to update their subject knowledge—72% wanted more CPD in that area, as against 60% for other subject teachers—while only 35% were satisfied with subject-related courses compared with 48% for secondary school teachers as a whole. The evaluation of the professional development provided by Science Learning Centre North East has been rated consistently “good” or “very good”.

12. Only 52% of secondary heads of science felt that CPD was encouraged by senior management compared to 67% of other heads of department. Even more striking, half of all secondary science teachers had had no subject-related professional development in the last five years. Within the North East, it is felt that the availability of well-qualified supply teachers is a key constraint in enabling teachers to confidently leave the classroom to undertake professional development. The Integrated Science Education Strategy addresses this by recommending that a cadre of specialist science supply teachers are trained and then employed within the Region to work within groups of schools and colleges in Collaborative Partnerships.

#### TEACHING SCIENCE: CURRICULUM AND ASSESSMENT

13. The national research suggests that the decline in interest in the physical sciences at A Level—and its vocational equivalent—and in higher education is linked to the way that the science curriculum is presented from primary schools onwards. Pupils experience a content heavy curriculum which is rigidly assessed.

14. Children at primary level are at a critical stage in developing ideas and views. However, research by Beggs and Murphy<sup>51</sup> and the Wellcome Trust<sup>52</sup> suggests that children’s interest in science is declining in the later primary years.

15. Throughout the Key Stages, the science curriculum is perceived to be excessively factual with an extensive content base and measures of assessment to be largely confined to the regurgitation of information. Research by Osborne and Collins<sup>53</sup> suggests that, as a result, many pupils find their experience of science off-putting. Although all pupils and their parents in their study considered science to be an important subject of study, pupils tended to view science as irrelevant to their everyday lives and only of value for passing an exam.

16. National research and the consultations undertaken in developing this Integrated Science Education Strategy provide a consistent picture of how best to improve the way that science is taught and assessed. It is felt that more emphasis needs to be placed on conceptual and abstract topics and science study needs to be more experimental, practical, investigative, observational and interpretational. It must provide both opportunities for personal autonomy as well as opportunities for group work and discussion. It should also include more contemporary examples. Pupils need to be encouraged to develop a clear understanding and capacity to think scientifically.

17. Many of these suggestions have been incorporated into the Review of Key Stage 4 and the resulting new curriculum which will be taught from September 2006. There is considerable optimism within the North East that the new curriculum will increase pupils’ interest in and enjoyment of science. However, it is felt that, in many schools, changes in the curriculum will need to be linked to improved facilities and resources to allow for a stimulating learning environment (see Paragrapg 23).

18. In primary, there is also an issue in terms of the relative status of science compared to the other key subjects of english and maths. More focus tends to be placed on english and maths as a result of the National Literacy Strategy and National Numeracy Strategy (and also on ICT as a result of the National Grid for Learning). As a consequence of this, science is not being given equal status with english and maths.

19. Over the past few years, primary students at Durham University on teaching practice within the Region have asked their schools how much time a week is spent on english, maths and science. The findings show that, on average, eight hours a week is spent on english, six hours on maths and no more than two hours on science.

<sup>49</sup> Council for Science and Technology. *Science Teachers: a report on supporting and developing the profession of science teaching in primary and secondary schools*. February 2000.

<sup>50</sup> *Believers, Seekers and Sceptics What teachers think about continuing professional development*, Wellcome Trust, January 2006.

<sup>51</sup> *Children’s attitudes to science in late primary*, Beggs and Murphy, QM Belfast, September 2005.

<sup>52</sup> *Primary Science in the UK: A Scoping Study*, Wellcome Trust, April 2005.

<sup>53</sup> *Pupils’ and Parents’ Views of the School Curriculum*, Osborne and Collins, King’s College London, January 2000.

20. QCA<sup>54</sup> has also highlighted that there is an issue relating to the transition from Key Stage 4 to AS/A2-level and has suggested a number of reasons which lead pupils to drop out of courses or choose not to take them. These include:

- the detail and depth of knowledge required which is significantly greater than for GCSE, especially for exams;
- the increased mathematical demand, especially in physics and chemistry;
- the increased amount of coursework; and
- the need for more independent learning and the difference in teaching style.

21. The transition between Key Stage 2 and 3 is also an important one. The DfES Research Report 443<sup>55</sup> found that, in maths and especially in science, pupils who made most progress after transferring from primary to secondary school did not express very positive attitudes to these subjects. They said that maths involved doing similar tasks in year 7 to those they had done in years 5 and 6. And, in year 7 science, pupils spent much of their time copying out the details of experiments or writing out instructions under the teacher's guidance; able pupils said that they were easily bored by these lessons.

22. As a result of this research evidence and our consultation across the Region, a key recommendation of the Integrated Science Education Strategy is the development of an enquiry-based curriculum model that will be implemented across all five Key Stages. Additionally, there is a recommendation for pupils at each Key Stage to have an entitlement to enrichment activities that motivate and develop interest in science beyond the classroom.

#### SCHOOLS AND SCHOOL LABORATORIES

23. Data from DfES shows a rising trend of success from the specialist science schools. The structure and role of these schools could be developed to provide a wider and deeper contribution. The growing number of science specialist schools means they are well-placed to take a leading role in developing effective practice.

24. Whilst the Building Schools for the Future (BSF) programme has been largely welcomed, the provision and timescale for BSF across the Region will leave many schools with inadequate science accommodation for many years. Teaching science in an impoverished environment, with out-dated equipment does little to stimulate young people to pursue science as a career.

#### LINKS BETWEEN SCHOOLS, UNIVERSITIES AND INDUSTRY

25. Research undertaken by the University of Northumbria<sup>56</sup> found that young people in all of the year groups did not understand the necessary steps involved in negotiating educational and employment pathways and that they were not making the links between qualifications and future lifestyles. Amongst pupils and their parents, there was a general lack of knowledge of the vocational route and how to apply for higher education and the costs involved.

26. Another study undertaken in the North East by Dobbs, Dodgson and Craddock<sup>57</sup> highlighted that, although teachers have an important role in helping young people to reach decisions about future educational and employment pathways, they require much more information and training on educational opportunities and they feel ill equipped to give advice about careers because they do not have up-to-date resources or information.

27. There is also a widely held perception<sup>58</sup> that careers in science, engineering and technology are very unattractive and hold little appeal for young people. This perception includes pay, career structure, work environment and status. From an industrial perspective, these perceptions appear not to be true. Graduates with degrees in computer science, maths, engineering and technology and the physical sciences attract higher salaries than graduates in the biological sciences or the social sciences. There is also a great diversity of career options within science, engineering and technology.

<sup>54</sup> Pupils' perspectives on science, QCA, 2003–04.

<sup>55</sup> Transfer and Transitions in the Middle Years of Schooling (7–14): Continuities and Discontinuities in Learning, DfES, July 2003.

<sup>56</sup> Young People's Attitudes to Education in the North East, Centre for Public Policy, University of Northumbria, September 2003.

<sup>57</sup> What Teachers Think: The role of teachers in shaping young people's attitudes to education and employment in NE England, Dobbs, Dodgson and Craddock, Aimhigher, June 2004.

<sup>58</sup> Europe needs more scientists, Report by the High Level Group on increasing Human Resources for Science and Technology in Europe, European Commission, 2004.

28. Within the North East, there is a wide range of initiatives. Many are considered to be of a high quality, targeted at raising aspirations of young people and improving their understanding of career opportunities. These include general initiatives such as *Aspire* and *Aimhigher* which include activities focused on science opportunities in higher education and employment. There are also activities which specifically focus on raising awareness of science careers such as those delivered by SETPoint North East, Children Challenging Industry, the NHS, North East Process Industries Cluster and Proctor and Gamble. However, there is a need to co-ordinate the range of activities, raise awareness of what works and ensure that all young people have exposure to them. The Integrated Science Education Strategy will achieve this coherence through the co-location of a STEM Support Centre with Science Learning Centre North East.

June 2006

### Memorandum by the Nuffield Foundation

#### 1. THE NUFFIELD FOUNDATION AND SCIENCE

The Nuffield Foundation is an independent charitable trust which has a long standing involvement in science education in schools. There are currently two main strands to this involvement. The first is the development of new curricula, materials and teaching methods to support the teaching of science in secondary schools, principally at GCSE and A level. The second is the support of individual young people who are considering a career in science. In this note we draw on this experience to comment on the third and fourth of the issues identified by the Committee: *Teaching Science and Schools*.

#### TEACHING SCIENCE

#### 2. THE IMPACT OF EXISTING SCHEMES DESIGNED TO HELP GENERATE ENTHUSIASM IN YOUNG PEOPLE FOR SCIENCE

2.1 Evidence presented to previous select committee inquiries has shown that the current national curriculum does not meet the needs of many young people, especially at key stage 4.

2.2 The House of Lords *Science and Society* report commented favourably on the recommendations of the *Beyond 2000 Report* (1998)—a report from a seminar series funded by the Foundation. The report made the case for finding better ways to meet the two main purposes of science education for 14–16 years olds:

- to develop the “scientific literacy” of all students in preparation for adult and working life; and
- to provide the foundations for more advanced courses in science.

2.3 The new programme of study from QCA, which applies from September 2006, has been strongly influenced by a model developed at the University of York based on the *Beyond 2000* recommendations. As a part of the Twenty First Century Science project the model has been piloted in 75 schools, starting in September 2003. Twenty First Century Science is a complete suite of GCSE courses developed jointly by the Nuffield Curriculum Centre and the University of York Science Education Group. Funding for the pilot has come principally from the Nuffield Foundation, the Wellcome Trust and the Salters Institute.

2.4 One of the objectives of the course is to address some of the problems that lead to young people’s disillusionment with school science; an overemphasis on factual recall, a lack of intellectual coherence across existing courses, and a lack of relevance to the real world of science and technology that students encounter outside the classroom. Our firm hope and belief is that the new, more flexible programme will enthuse young people and encourage more of them to study science post-16.

2.5 It is however too early to say whether this objective will be achieved. Significant effort has been put in to evaluation of the pilots and three research teams will be reporting on different aspects of the project in the autumn of 2006. However the policy decision to go ahead with the new curriculum was taken long before the evaluation of the pilot was complete. Given the inevitable challenges of the first cohort passing through a complex pilot, more reliable data will be obtained from the second, third and subsequent cohorts.

2.6 The new Twenty First Century Science courses are available to all schools from September 2006 supported by a comprehensive range of print and electronic resources, published by OUP. Schools in England are free to choose from four GCSE programmes from the awarding bodies of which the Twenty First Century Science programme (offered by the OCR board) is one.

### 3. THE ADEQUACY OF PROFESSIONAL SUPPORT FOR SCIENCE TEACHERS

3.1 When the Nuffield Curriculum Centre disseminates a new curriculum project it works closely with all agencies that provide support for teachers. Currently this is particularly important for the new GCSE courses and Twenty First Century Science in particular.

3.2 In the last 18 months the director of the Nuffield Curriculum Centre has chaired a series of meetings convened by the Royal Society and the Association for Science education. The purpose of the meetings has been to ensure that science teachers get the information, guidance and support they need in the period running up to the launch of new Science GCSEs in September 2006 and beyond. The main focus of the meetings has been on the need to make sure that all the players in the field understand what they are doing and act in ways that are complementary rather than competing.

3.3 It is striking how many organisations have a stake in providing support, but none of them has the authority to make sure that the provision of support happens in ways that make sense to teachers and are both affordable and accessible on an appropriate scale.

3.4 Official bodies with an interest include DfES, TDA, OFSTED and QCA. Providers of support include the National Strategy and their consultants, the National and Regional Science Learning Centres, the Specialist Schools Trust, Local Authority advisers and inspectors, the Association for Science Education as well as independent providers of training including some science-based industries. In London there is also London Science Challenge.

3.5 This diversity is confusing and means that there is a danger that resources to support teachers are dissipated. The bulk of the funding for professional development is delegated to schools where the priorities may not be the needs of science teachers, so that what is on offer sometimes cannot be taken up by those that need support.

### 4. THE ROLE OF THE PRACTICAL IN TEACHING SCIENCE

4.1 The Nuffield Foundation has supported investigative science teaching for many years. Practical and experimental science continues to feature largely in new courses developed by the Nuffield Curriculum Centre. Today all guidance on practical work is checked carefully by CLEAPSS (Consortium of Local Education Authorities for the Provision of Science Services). Our experience is that health and safety regulations have not prevented us building into courses a wide range of appealing practical work. In our new, work-related courses we have been able to introduce new practical activities in vocational contexts uninhibited by regulation.

4.2 With the Institute of Physics we have developed the “Practical Physics” web site (<http://www.practicalphysics.org/>) which already features over 400 experiments for the 14–19 age range. In time there will be hundreds more. In September 2006 we, and the Royal Society of Chemistry, will be launching a similar site for Chemistry. Both sites are intended to support all teachers of physics and chemistry and not just those with specialist backgrounds in these subjects.

4.3 Practical work is not inherently good. It can lead to time wasting unless included in a course for a clear purpose. The purposes vary with the context and include:

- giving students experience of phenomena in ways that lead to new conceptual understanding;
- the development of hands-on practical skills;
- offering experience of the methods of science and the evaluation of data, as well as; and
- providing the challenge of investigations planned and carried through by students.

## SCHOOLS

### 5. LINKS BETWEEN SCHOOLS, UNIVERSITIES AND INDUSTRY, TO FACILITATE SCIENCE TEACHING

5.1 The work of the Nuffield Curriculum Centre in developing new science courses is enriched through collaboration with universities and industry. These collaborations help to keep science courses up to date. They also provide the case studies to teach basic science well in modern contexts. The Twenty First Century Science courses and the (A level) Salters-Nuffield Biology course provide many examples of the value of close partnership between curriculum developers, teachers and scientists working at the frontiers.

5.2 With the support of the Gatsby Charitable Foundation, we have recently produced a series of sets of video clips to illustrate the practical importance of school science in the workplace. These are for use in GCSE Applied Science courses. The cooperation from a wide range of industries, public services and commercial organisations has been wholehearted and very valuable.

5.3 Finally we should mention the Nuffield Science Bursary scheme. The aim of the scheme is to give students who are interested in science a chance to work alongside practising scientists by contributing to science or technology-based projects. Post-16 students on Advanced science and science-based technology courses in schools and colleges are given a bursary that enables them to work on a project in a university, research institution, field centre or in industry, for a four week period during the summer vacation. Students carry out projects that are well defined, allow the students to take some personal responsibility, and also contribute to the work of the host organisation. Over 650 students benefit from this experience each year.

5.4 The scheme has been very successful and the Foundation has decided to expand it significantly, with the aim of offering bursaries to some 2,000 students a year. The scheme already benefits hugely from partnerships with many other organisations which provide funding, student placements, and many other forms of support. These include the Wellcome Trust, the Royal Society, several of the Research Councils and many Research Institutes, Universities, industrial companies and other science-based organisations. As we expand the scheme we hope to build on these partnerships, and form many new ones.

5.5 A similar scheme run by the Foundation offers bursaries to second year science undergraduates to enable them to take part in extended research projects over the summer vacation, usually in their own universities. The Foundation has decided to extend this scheme too, with a target of supporting 750 students each year.

*June 2006*

### **Memorandum by OCR**

#### **THE ADEQUACY OF PROFESSIONAL SUPPORT FOR TEACHERS**

As an awarding body, OCR offers general and vocational qualifications in the sciences, including Entry Level, GCSE, GCE, and Nationals. These qualifications are taken by very large numbers of candidates each year, for example approximately 120,000 candidates take OCR qualifications in GCSE sciences.

It is clearly important for students that their teachers understand the content of these courses, so that appropriate teaching schemes can be developed that enable students to demonstrate the skills, knowledge and understanding which will be assessed. OCR therefore understands the importance of the provision of Continuing Professional Development (CPD) and makes available to teachers a wide variety of courses covering all of our qualifications. These include task setting and marking of internally assessed coursework, preparing to deliver new qualifications, courses for teachers new to the profession, teaching practical skills, and giving feedback from previous examination sessions to assist teachers in preparing candidates. These courses are very popular indeed: in the last year 102 separate events were held and a total of 3,468 teachers attended these sessions. In addition, OCR staff and consultants attended numerous events organised by other organisations, including Science Learning Centres, LEAs, professional bodies such as the ASE and groups of Centres, to contribute expertise on assessment issues. For teachers to be able to justify their absence from classes and the costs of attendance, travelling and supply cover, OCR is acutely aware that the content of any courses must be strictly relevant and directly applicable in the classroom or science laboratory, and of very high quality. Feedback from delegates is always very encouraging: 96% of OCR events are rated "Excellent" or "Good" by at least 80% of participants.

The role of teachers in encouraging students to take A level courses in the sciences is critical. Although teacher recruitment and training is not directly relevant to the work of awarding bodies, we regularly see the results of incorrect teaching and are aware of the impact this has on candidates. We are also aware from our training courses that not all science teachers are specialists in the subject they are delivering, and increasingly our Reports to Centres have included "teaching tips" to promote good teaching.

#### **THE IMPACT OF EXISTING SCHEMES DESIGNED TO HELP GENERATE ENTHUSIASM IN YOUNG PEOPLE FOR SCIENCE SUBJECTS**

There is concern nationally about the numbers of students taking the sciences post-16 and OCR shares this concern. The point at which students make this choice is usually in Year 11, during the last year of their GCSE courses, and they are unlikely to take sciences post-16 if their GCSE courses seem boring and irrelevant. The report of the House of Commons Science and Technology Committee (ref: Science and Education From

14–19: Government Response to the Committee’s Third Report, October 2002) indicated that this was indeed often the case and OCR is therefore very optimistic that the exciting changes being made to GCSE science courses will have a positive impact. OCR pioneered these changes with the Twenty First Century Science suite and Science D pilot GCSE specifications which have run in schools since September 2003; the new qualifications based on these pilots and on the new QCA Science Criteria start teaching in September 2006. The introduction of the “How Science Works” section into the QCA Science Criteria underpins these changes. It is intended to make courses relevant to students by showing how scientists work and how the implications and applications of science impact on our lives, as exemplified by the appearance daily of science stories in the media. OCR has embraced these changes in our new specifications and we are very encouraged indeed by the enthusiastic response to them from teachers, many of whom are clearly equally frustrated by the current curriculum. A comment from Hugh Williets, Head of Science at Settle College, one of the Twenty First Century pilot schools, is typical: “The most stimulating, exciting, and rewarding time I have ever experienced in teaching. Our year 11 students are increasingly positive about science”. Teachers of the same pilot scheme also report that pupils no longer ask “why do I have to learn this?”, clearly seeing the relevance of science in the classroom, for those not intending to pursue science beyond key stage 4.

One other significant change to science in Key Stage 4 is the introduction of courses in applied science. Teaching, leading to a qualification in GCSE Applied Science (Double Award), started in September 2003 and there has been a steady increase in candidature over the last three years. OCR anticipates that the revised specification which starts teaching in September 2006 will attract much higher numbers and, as an alternative, students also now have the opportunity to take GCSE Additional Applied Science in conjunction with GCSE Science to fulfil their entitlement to study two GCSEs in science subjects. OCR’s provision in this area also includes the new National in Science which has a three unit Award and six unit Certificate. Applied science courses have strong vocational links and their assessment is based to a much greater extent on investigative work. They therefore appeal to students whose favoured learning style is concrete rather than abstract and have the potential to retain the interest of students who might previously have rejected science.

One of the complaints made by very able students about the current curriculum is that it is insufficiently challenging and is geared to those who are able to remember most facts rather than to those who understand and apply scientific knowledge (ref: Student Review of the Science Curriculum— Major Findings. Planet Science, Institute of Education, Science Museum, 2002). In discussing the changes to Key Stage 4 with teachers, it has been interesting to note how many intend to provide accelerated pathways for their most able students, for example completing Key Stage 3 work at the end of Year 8, GCSE Science at the end of Year 9 and GCSE Additional Science at the end of Year 10. Year 11 will then be available for further work in the sciences, perhaps to take GCSEs in the separate sciences (Biology, Chemistry and Physics). Alternatively, such students might study the separate sciences over three years (from Year 9 to Year 11). The 2006 Budget (ref: Budget 2006 paragraph 3.79, March 2006, HM Treasury) included a commitment to an entitlement for students achieving Level 6 or above in Key Stage 3 to take GCSEs in the three separate sciences in Key Stage 4. Unless an accelerated pathway as described is adopted, one outcome of this entitlement for these students could be that the rest of their curriculum is impoverished. Students taking advantage of this entitlement are likely to be those already committed to science, and so the impact of the change on uptake of science post-16 is uncertain. An alternative approach, which OCR has promoted, is that for such very able students, “stamp collecting” additional high grade Level 2 GCSE qualifications may be a less attractive option than moving on to qualifications at Level 3, such as GCE AS in Science, as a bridge into A Level work.

Overall, OCR believes that the nature of the courses and the much wider range of choices available in the new science curriculum in Key Stage 4 will better meet the needs of individual students, and will engage and enthuse a larger number of students and make more likely their continued interest in science. The next step is to ensure that the opportunities available to these students post-16 are equally exciting and provide appropriate progression routes from Key Stage 4 and into Further or Higher Education, or employment.

The development of new GCE A/AS specifications in the sciences is now under way; teaching for these new courses starts in September 2008. The draft QCA Criteria for the sciences has incorporated “How Science Works”, and this should mean that students will see a clear progression from GCSE and develop a better understanding of the nature of science, of the links between the sciences, and of the relevance of science to everyday life. The Criteria are sufficiently flexible to permit the development of a range of qualifications in each subject area, so providing Centres with choices in terms of content, approaches to teaching and learning, and assessment. OCR’s GCE A/AS specifications in Applied Science were introduced for start of teaching in September 2005. These innovative qualifications will provide appropriate progression routes for the increasing numbers of students taking courses in applied science in Key Stage 4 and we believe that this area offers an important opportunity to significantly increase the numbers of students taking sciences to AS and A Level. It

is important though that qualifications in applied science are seen as being of equal value to those in the more traditional biology, chemistry and physics when these students wish to move on to Further or Higher Education.

#### THE ROLE OF THE PRACTICAL IN TEACHING SCIENCE

For most students, it is the practical work in science which stimulates at least the initial interest in the subject. To maintain and develop this interest, investigative activities, including practical work, are key and the first responsibility of developers of new qualifications in the sciences is not to overload the content of specifications so that there is sufficient time within the course for such activities. However, many able students report finding the practical work provided for them formulaic, repetitive, uninteresting and lacking in challenge (ref Student Review of the Science Curriculum—Major Findings. Planet Science, Institute of Education, Science Museum, 2002). For many science teachers too, much of the pleasure of teaching science comes from practical work and the challenge to the teacher is therefore to provide appropriately diverse, challenging, and imaginative activities to develop students' skills and their knowledge and understanding of science. These activities should certainly include practical work but also investigative activities using ICT (for example to access secondary data on spreadsheets) group discussions, modelling, making presentations etc. Good teachers will do all of these things, given reasonable time and opportunity, but it is certainly the case that the assessment requirements of qualifications, as detailed in specifications, can encourage teachers to explore new approaches. In the assessment of coursework for OCR's new GCSE specifications, for example, there is credit for the assessment of individual practical skills, for whole investigations, case studies, and tasks involving the manipulation of data.

However, it has been widely recognised that it is increasingly difficult for teachers to assess coursework fairly, with the opportunities now available to students for plagiarism using the Internet, for example. The pressure on teachers to maximise the performances of their students also tends to lead to the use of a very small number of "successful" coursework tasks which are practiced beforehand, and so become repetitive and dull. In OCR's new GCSE specifications we have tried to return to the initial concept of coursework—that it should be the assessment of "work done during the course", rather than a "bolt-on" additional element. In the Gateway GCSE specifications, we have addressed these issues by providing teachers with a range of OCR-set tasks, renewed annually, which are engaging and challenging for students.

Where assessment of practical skills is by coursework, for example the assessment of a practical investigation, there is no advantage to the candidate in terms of credit for the qualification and therefore no incentive to the teacher, to do practical work beyond that required for assessment, and teachers may feel that theory work needs to take precedence. In the development of OCR's new GCE A/AS specifications in the sciences, consideration is being given to ways in which further encouragement could be given to teachers to integrate practical and investigative work into courses to provide students with a varied and interesting experience.

*June 2006*

#### **Memorandum by Dr John Oversby**

##### MY DETAILS

My response is a personal one.

As a Lecturer in Science Education, I am Course Leader for the PGCE/GTP Secondary Science Course at The University of Reading and have been so since 1993.

I am Chair of the Royal Society of Chemistry (RSC) Thames Valley Section and a member of the RSC Chemical Education Research Group. I am also a newly elected member of the RSC Committee for Local Sections.

I am an active member of The Association for Science Education (ASE). I represent teachers in Berkshire and Oxfordshire on the ASE Council, and chair the local region. I am chair of the national ASE Research Committee. I am a member of the ASE Chartered Science Teacher Registration Board, representing the ASE Council. I am a committee member of The Association of Tutors in Science Education, part of the ASE.

I am a Trustee of The National Foundation for Education Research on behalf of ASE.



### THE CURRENT SITUATION

- Recruitment of specialist secondary science teachers remains a challenge in the Thames Valley. The majority of applicants are biology specialists, many with no experience of chemistry or physics past the age of 16. Physicists frequently only have physics as their only post-16 science subject. Rejection rates for applicants, arising from lack of adequate subject knowledge or insufficient experience with adolescents, is running at about 65%. It is my view that the quality of applicants has decreased as the total numbers have increased. There are more with lower degree results, from 2ii downwards, with modest A levels of grades D and E, and with a mediocre range of GCSE results. A lower proportion has any experience of adolescents, let alone science with adolescents.
- The majority of applicants to Reading are mature students, ranging in age from 21 to 57 this year. Recent graduates are only around a quarter of applicants. This suggests that teaching is still not attracting sufficient undergraduates in science.
- In this year, around 45% of the course was biology specialists, 20% physicist and 35% chemists. This is a lower proportion of biologists than normal. My intake was 39.
- Schools are requesting physicists and chemists as applicants for teacher posts but are recruiting biologists when no others are available.
- The majority of KS 3 science is taught in most Thames Valley Schools by biologists. This may explain why students at KS 3 find biology to be more popular than either chemistry or physics (ROSE project, Beyond 2000 report).
- Turnover in many Thames Valley Schools remains high. Anecdotal evidence suggests that turnover varies from 200% over two years in one Reading Partnership school, to a low of 20% in another. Turnover in independent schools appears to be much lower than in maintained schools.
- There appears to be a drift of well-qualified and experienced science teachers from the maintained sector to the independent sector. This is in addition to the low rate of direct recruitment of NQTs to the independent sector. This drift is starving maintained schools of an adequate supply of good experienced teachers. One effect of this is that mentoring of new teachers is an additional workload on the remaining experienced staff.
- Availability of training places for secondary science teachers is being challenged by a number of factors. High turnover often leads to schools taking a break from initial teacher education as they seek to deal with large numbers of new full-time staff who need to be inducted and trained. Increased initial teacher education targets in many institutions in the area lead to increased competitive demands on those schools willing to take trainees. The GTP route has also led to the loss of places in university initial teacher education courses. Partly this is because schools replace an offer of two university initial teacher education places with one GTP place, explained by the extra-perceived demands of a GTP student. At Reading, for PGCE science, placement offers now exactly match target numbers leaving no room for expansion, problems in deselecting schools, and an acceptance of a much wider range of quality in schools. In previous years there was a small surplus of places available.
- Low pay among lecturers and inadequate funding of initial teacher education in HE means that workload among HE staff is reaching breaking point.

### ATTRACTING SCIENCE TEACHERS

- There are too few part time and flexible routes into science teaching. These are likely to be more costly than full time routes and should attract greater funding.
- Although it appears that schools are more willing to offer part time employment, there is still too much reluctance to do so. Thus, those that wish to teach part time still find it difficult to find an appropriate and manageable post to do so. A campaign to sensitise head teachers to this route might be undertaken.
- The incentives that exist to attract new graduates and those from other professions appear to be largely adequate at this time.
- The effectiveness of teacher training in science subjects remains a challenge in the light of the requirement to spend large blocks of time on school placement during a PGCE course. This leaves too little time to work on subject knowledge. Enhancement courses do not appear to be popular among those whom I interview but booster courses are more successful. There are too few of these within easy reach of the Reading area. In general it should be possible for a would-be applicant to

attend a two-week booster course in any or each of the major sciences, including biology, with a maximum of one hour's travelling time.

- In parallel to boosting subject knowledge, courses in developing motivation towards, for example, chemistry and physics for biologists, should be established. We need enthusiastic teachers with sufficient knowledge and this cannot be achieved without attending to affective issues.

#### TEACHING SCIENCE

- The National Science Strategy (formerly Key Stage 3 Strategy) has made valuable contributions to developing both science knowledge and pedagogy.
- Newly qualified teachers in the Thames Valley have more generic training during induction than specific science training. There should be more funds for supply cover as well as course provision. However, a major barrier is the lack of supply cover caused by the endemic shortage of science teachers. This leads to head teachers being reluctant to let NQTs attend out of school courses. This could be ameliorated to some extent by paying NQTs extra for attending courses during school holidays.
- The effect of changes in the curriculum on attracting/retaining science teachers. Discussions in my teacher-researcher group suggests that the new curriculum has been too rapidly introduced with too little support for the major changes in philosophy and pedagogy needed for the new KS 4 science syllabus. Regretfully, this change, which I welcome in principle, could lead to lower morale among science teachers. Changes need adequate time and resources to implement. The consequent changes to KS 3 and post 16 courses are regarded with equal suspicion, given the present unsatisfactory way that the changes for KS 4 were implemented. I did point this out at a Royal Society meeting in March 2005 but was told that everything would be in place on time by a DfES representative.
- The role of the practical in teaching science. The Chemical Education Research Group of the RSC on which I sit has just carried out a small research project on this topic. The project was the subject of a lecture at the ASE Conference in Reading in January of this year. A major outcome of that study was a determination by some teachers to carry on despite the negative impact of department, school, LEA and national policies on school practical work, especially safety. In ASE, I am a member of a committee that overlooks the Safeguards Committee who regularly report the effects of these policies and the never-ending efforts by committee members to put the story straight, especially in regard to so-called banned experiments. It is my view that these concerns emanate from a lack of confidence, especially in chemistry when taught by non-chemists. Practical work is still seen as routine and disengaging. Real investigations, where the learners have some real choice, appear to be rare below A level and this undoubtedly contributes to the declining numbers at A level. A further factor is the often-weak state of practical resources I see in my frequent visits to schools. While there has been a step change in some schools towards using ICT, at least as far as equipment is concerned, practical equipment seems depressingly familiar to someone brought up in the 1970s as a new teacher. I would like to see more funding spent on good equipment such as high quality microscopes for KS 3 and 4, for more power packs for use in physics at KS 3 and 4, and for more accurate balances for use in chemistry at the same key stages.

#### SCHOOLS

- I have referred to school laboratories and equipment above. In parallel to providing better resources, more training for teachers in using them is needed. This butts against the constraints of a shortage of teachers and of teacher trainers mentioned above. In the light of the DfES just-in-time model of teacher supply, which turns out to be insufficient in spite of its limited horizons, the number of science teachers available for supporting classes of those on training needs to be substantially increased. The goal of independent trusts to manage separate schools contradicts the need, as I perceive it, of a co-ordinated approach to teacher development.
- Links between all related bodies and schools are an essential component of raising interest in science. As part of the work of the local RSC committee that I chair, thousands of GCSE pupils attend Science at Work events each year, co-ordinated by Phil Smith, the Education Officer on our committee. Close links with LEAs through advisers and consultants are a very significant aspect of developing the quality of science teachers. I am in discussions with the Reading BC adviser about the establishment of chemistry and physics enhancement courses for the Borough teachers. LEA science consultants are senior members of our local ASE committee and frequently contribute to courses to

enhance quality. Universities can not only offer MA courses, well supported by the TDA as they are in Reading, but can offer subject enhancement courses of their own. My university already runs a chemistry teachers' group to provide support and short courses for Thames Valley A level teachers, in the School of Chemistry. At present the university funds these but the DfES should recognise their value and make appropriate financial contributions.

#### OVERALL

The state of science teaching in schools is affected by many factors. Although there is no immediate solution, we can make a start by providing subject transformation courses for existing teachers, by developing the nature of school practical work at 11–16 to include real investigations and real examples of how science works, by providing sufficient staff resource for teachers to attend effective subject development, and by modest funding contributions to a wide range of initiatives mentioned above. We must attend to the affective features of science teaching as much as the cognitive and manipulative. We need more research data on regional variations in teacher supply. There are some very useful examples of successes on which we can build.

*June 2006*

### **Memorandum by the Particle Physics and Astronomy Research Council**

#### INQUIRY TO EXAMINE SCIENCE TEACHING IN SCHOOLS

##### THE CURRENT SITUATION

1. As a Research Council we are able to link contemporary science with schools and teachers to support national agendas. We note with concern the recent evidence<sup>59,60</sup> showing that the physics content of the National Curriculum in England and Wales is often taught by teachers who are teaching outside their specialism. While non-specialists can provide a high-standard of teaching, they are unlikely to have the subject knowledge or confidence to enable them to bring exciting contemporary physics (particularly space, astronomy and particle physics) into the classroom. This is likely to be reflected in continuing problems with attracting students to study physics post-16 with knock-on effects to university physics courses and beyond.

##### ATTRACTING SCIENCE TEACHERS

2. Our experience of working with teachers suggests that many science teachers lose touch with the community of scientists working in research and/or industry. Schemes such as the Research Councils' "Researchers in Residence" programme or the Science and Engineering Ambassadors Scheme (SEAS) can go some way to addressing this issue. Other approaches to maintaining links between teachers and science, such as support for teacher placements in Research or Industry, may help both to attract and retain science teachers.

##### TEACHING SCIENCE

3. The establishment of Science Learning Centres has provided a new focus for the continuing professional development of teachers (CPD). PPARC has worked directly (and through Research Councils UK) with the National Centre and some regional centres to develop and support CPD focussing on the contemporary science which we fund. The response by teachers to these, and other "science update" events, has been uniformly enthusiastic—as one teacher put it "this reminds me why I wanted to teach physics". However, we note the difficulty that some centres have had in filling such courses. This appears to reflect both the cost of attendance (and necessary supply cover for teachers) and also the priority given by headteachers to CPD which is more directly pedagogic. In our view, teachers should have an entitlement—or perhaps even a requirement—for CPD which covers both pedagogy and subject-specific knowledge. (We understand that in Scotland, following the McCrone Report, teachers are expected to undertake CPD work to qualify for the standard terms and conditions, but this approach does not seem to have been adopted in England).

<sup>59</sup> Alan Smithers and Pamela Robinson, "Physics in Schools and Colleges: Teacher Deployment and Student Outcomes, (University of Buckingham), November 2005.

<sup>60</sup> Mathematics and Science in Secondary Schools: The Deployment of Teachers and Support Staff to Deliver the Curriculum (DfES Research Report 708), January 2006.

4. The study of astronomy and space is known<sup>61</sup> to be particularly attractive to school students. This has been recognised in Scotland, where “Space” has become an important strand of the science curriculum. The Scottish Space School project, supported by the Scottish Executive, reaches large numbers of school students in Scotland. In the wider UK context, there are a large number of schemes, some supported by PPARC, aimed at making use of this excitement in schools, as noted by Professor Martin Barstow in his report “Bringing Space into School Science”<sup>62</sup>. Barstow makes a number of recommendations including improved co-ordination of Space-based educational activities and the use of “Space” as a “flagship topic” in schools.
5. Evidence of the impact of using “Space” is provided by Scottish Space School, who track participants. Their results<sup>63</sup> for 53 students who attended a School and then applied to University are:

<i>Influence of Space School on Course/Career Choice</i>	<i>Nos</i>
Directly influenced the decision to follow science/engineering course or career	25
Already wanted to do a SET-related course/career but space school reinforced this choice	12
Didn't influence choice but helped in other ways	12
No influence and may actually have turned off choice of SET course/career	4

6. The recent development of robotic telescopes<sup>64,65,66</sup> and their use by schools can bring astronomical observations directly into the classroom. They offer new opportunities for schools to order their own astronomical observations (or in the case of the Faulkes Telescopes take direct control of the telescope) and carry out curriculum-linked or extension projects. Educational programmes are being developed, some with funding from PPARC, and early responses from teachers and pupils are extremely positive. To ensure wider use of these facilities, teaching specifications and schemes of work could encourage teachers to use them. A wide and continuing programme of CPD will also be needed.

16 June 2006

### **Memorandum by the Qualifications and Curriculum Authority, Curriculum Division**

#### **TEACHING SCIENCE—THE CURRICULUM AND QUALIFICATIONS**

1. QCA is responsible for the development of the school curriculum, and the regulation of external qualifications.

#### **A NEW CURRICULUM MODEL FOR SCIENCE**

2. The Science curriculum has a dual role to play within education. It should ensure that:
- 2.1 All pupils have sufficient understanding of science for their role as citizens, now and in the future.
  - 2.2 It prepares those who will go on to further study and careers in, and related to, science.
3. Therefore, science education must:
- 3.1 Provide skills, understanding and knowledge to make sense of science now and in the future;
  - 3.2 Provide skills, understanding and knowledge to form a sound basis for further study;
  - 3.3 Motivate and engage young people so that they learn more effectively;
  - 3.4 Motivate and engage young people so that more of them want to continue to study science and make it their career.
4. The science curriculum must be relevant to the young people who are learning so that they can make sense of it and relate it to their existing knowledge and worldview. Only if they can do this will they be both challenged and enabled to extend their learning and develop their understanding of the world. Equipping them effectively with skills and understanding will take them beyond mere accumulation of knowledge, which so easily becomes out-of-date, towards becoming lifelong learners able to adapt to the rapidly changing technological world they will live and work in.

<sup>61</sup> See, for example, Osborne, J and Collins, S. “Pupils’ and Parents’ Views of the School Science Curriculum”, (King’s College London), January 2000.

<sup>62</sup> See Barstow, M. “Bringing Space into School Science”, (BNSC/PPARC) October 2005 <http://www.pparc.ac.uk/Ed/barstowpage.asp>

<sup>63</sup> See “The Education and Skills Case for Space” by P Spencer and G Hulbert (report to UK space agencies) and also [www.careers-scotland.org.uk](http://www.careers-scotland.org.uk)

<sup>64</sup> The Faulkes Telescope Project <http://www.faulkes-telescope.com/>

<sup>65</sup> The National Schools Observatory <http://www.schoolsobservatory.org.uk/>

<sup>66</sup> The Bradford Telescope <http://www.telescope.org/>

5. In 1998, the Nuffield Foundation published a report entitled *Beyond 2000* indicating that science in schools was neither encouraging sufficient numbers of students to study science further nor adequately addressing the science needs of future citizens. Ofsted subject reports and QCA's monitoring of the curriculum, among others, also provided evidence that science, particularly in secondary schools, was failing to engage and motivate pupils.
6. In 2000, as a result of these findings, QCA initiated a curriculum project entitled *Bringing school science into line with the changing needs of the 21st Century*. King's College London and the Universities of Southampton, Leeds and York were commissioned to investigate what students would need in order to become scientifically literate citizens, what should constitute a curriculum to meet those needs and how students' learning in a new and different science curriculum could be assessed.
7. Following on from their report on an appropriate curriculum, York University was asked to suggest models of how it could be implemented. They put forward a single model capable of meeting the needs of all future citizens, as well as those who would also become practising scientists. Following a tendering process, the OCR awarding body was then commissioned to produce a suite of pilot GCSE qualifications to match the curriculum model.
8. During the second part of QCA's curriculum project, *Bringing school science into line with the changing needs of the 21st Century*, the Secretary of State asked QCA to review and revise the national curriculum programme of study for science at key stage 4 in the light of widespread concern about the fitness for purpose of the current science curriculum. This work was undertaken, followed by the necessary accompanying revision of the GCSE science subject criteria. Both were widely consulted upon during the development process. The science education and wider science communities, awarding bodies, learned societies, schools, colleges, universities and employers were among the wide range of stakeholders who contributed to the development of both the programme of study and the subject criteria.
9. The new key stage 4 programme of study contains eight sections divided into:

#### HOW SCIENCE WORKS INCLUDING:

##### *Data, evidence, theories and explanations*

#### 1. Pupils should be taught:

- (a) how scientific data can be collected and analysed;
- (b) how interpretation of data, using creative thought, provides evidence to test ideas and develop theories;
- (c) how explanations of many phenomena can be developed using scientific theories, models and ideas; and
- (d) that there are some questions that science cannot currently answer, and some that science cannot address.

##### *Practical and enquiry skills*

#### 2. Pupils should be taught to:

- (a) plan to test a scientific idea, answer a scientific question, or solve a scientific problem;
- (b) collect data from primary or secondary sources, including using ICT sources and tools;
- (c) work accurately and safely, individually and with others, when collecting first-hand data; and
- (d) evaluate methods of collection of data and consider their validity and reliability as evidence.

##### *Communication skills*

#### 3. Pupils should be taught to:

- (a) recall, analyse, interpret, apply and question scientific information or ideas;
- (b) use both qualitative and quantitative approaches; and
- (c) present information, develop an argument and draw a conclusion, using scientific, technical and mathematical language, conventions and symbols and ICT tools.

*Applications and implications of science*

4. Pupils should be taught:

- (a) about the use of contemporary scientific and technological developments and their benefits, drawbacks and risks;
- (b) to consider how and why decisions about science and technology are made, including those that raise ethical issues, and about the social, economic and environmental effects of such decisions; and
- (c) how uncertainties in scientific knowledge and scientific ideas change over time and about the role of the scientific community in validating these changes.

**BREADTH OF STUDY***Organisms and health*

5. In their study of science, the following should be covered:

- (a) organisms are interdependent and adapted to their environments;
- (b) variation within species can lead to evolutionary changes and similarities and differences between species can be measured and classified;
- (c) the ways in which organisms function are related to the genes in their cells; and
- (d) chemical and electrical signals enable body systems to respond to internal and external changes, in order to maintain the body in an optimal state; and
- (e) human health is affected by a range of environmental and inherited factors, by the use and misuse of drugs and by medical treatments.

*Chemical and material behaviour*

6. In their study of science, the following should be covered:

- (a) chemical change takes place by the rearrangement of atoms in substances;
- (b) there are patterns in the chemical reactions between substances;
- (c) new materials are made from natural resources by chemical reactions;
- (d) the properties of a material determine its uses.

*Energy, electricity and radiations*

7. In their study of science, the following should be covered:

- (a) energy transfers can be measured and their efficiency calculated, which is important in considering the economic costs and environmental effects of energy use;
- (b) electrical power is readily transferred and controlled, and can be used in a range of different situations;
- (c) radiations, including ionising radiations, can transfer energy; and
- (d) radiations in the form of waves can be used for communication.

*Environment, Earth and universe*

8. In their study of science, the following should be covered:

- (a) the effects of human activity on the environment can be assessed using living and non-living indicators;
- (b) the surface and the atmosphere of the Earth have changed since the Earth's origin and are changing at present; and
- (c) the solar system is part of the universe, which has changed since its origin and continues to show long-term changes.

10. The new key stage 4 programme of study was published early in 2004 and the GCSE science subject criteria in November of that year. Awarding bodies were closely involved in the work to produce the programme of study and the subject criteria. They have developed new GCSE science specifications, which were first

submitted to QCA in early April 2005. Most of these specifications were accredited and made available to centres by October 2005. Centres are now in the process of planning their provision for first teaching of the new specifications in September 2006.

11. The new science programme of study for KS4 is based on “How science works”, sometimes referred to as “science process”. This is a clear signal that science teaching needs to change to match the needs of learners today and in the future.

12. The new programme of study is also designed to encourage the use of a wide variety of practical work in science. Practical work is an essential part of developing the skills, understanding and knowledge of “How science works”. It also engages and motivates young people, increasing their interest and supporting aspirations towards further study and science related work.

13. The new programme of study clearly indicates that “How science works” must be taught in the context of the breadth of study, ensuring a sound knowledge base. This leaves room for flexibility of interpretation and enabling a variety of teaching approaches as well as providing a sound basis for further study. The breadth of study covers key contexts from the physical and biological sciences.

14. There are outstanding examples of teaching science in schools based on the current national curriculum. These include the use of relevant, up-to-date contexts, teaching through practical activities, discussion and debate on current scientific issues, and linking with universities and industry. However, this good practice needs to be spread more widely. QCA has consulted widely, conducted research and developed a science curriculum to actively promote such good practice in teaching.

15. New GCSE science specifications that reflect the new programme of study have been developed and accredited for first teaching in September 2006.

16. Three concerns have been raised in terms of this new programme of study, centred on the notion that the new GCSEs are “dumbed down”. These are that:

- Some higher education institutions believe that students studying for a degree have less prior knowledge now than they did 20 years ago and that A level is no longer an adequate preparation for further study. There is no empirical evidence to support these assertions. QCA has, however, fully involved higher education institutions in the consultation over the changes to the key stage 4 programme of study and revisions to A level. They have been fully engaged in the process and support the move to more emphasis on skills.
- There is limited content in the new programme of study compared with the old programme of study. This is not true. There has been a shift towards a more appropriate balance between content and skills but the key concepts that students need to grasp to progress to appropriate level 3 qualifications remain. It is the contexts through which these concepts are introduced that have changed to become more contemporary to engage students in science.
- Students no longer need to write anything to get a GCSE in science as all of their assessments are in the form of multiple choice/objective questions. This also is not true. All GCSEs from 2006 require some form of written assessment. However, objective testing is widely recognised as a reliable method of assessing many different aspects of knowledge, understanding and capability. When combined with other forms of assessment, such as written responses, it can form part of effective and comprehensive assessment arrangements for a wide variety of courses.

#### THE EFFECT ON TEACHERS AND TEACHING

17. The change in emphasis to a more even balance between “How science works” and factual science content has clear implications for teaching. Teachers need training, support and guidance to adapt to a model of science teaching that is unfamiliar to many of them. They also need to develop appropriate approaches to teach this model of science effectively. QCA has produced guidance and is developing further support online. Further training and support is being provided by a wide variety of organisations, including SNS, TDA, SLCs and SSAT, and this will need to be sustained in the long-term.

18. Increased choice and flexibility in what, and how, to teach may help to improve both retention and recruitment of science teachers.

## CHANGES COMPLEMENTING THE KEY STAGE 4 DEVELOPMENTS

19. QCA is now reviewing the key stage 3 programme of study and the GCE Science subjects criteria in accordance with the 14–19 Education and Skills White Paper (February 2004).

20. The main thrust of the revision at key stage 3 is to reduce prescription and overlap between subjects, thus allowing schools greater flexibility to design a curriculum tailored to their own particular needs and circumstances. At the same time the science programme of study is to be aligned with the new programme of study for science at key stage 4. A draft is currently undergoing informal consultation, with formal consultation due to in early 2007.

21. GCEs in Science subjects are being reviewed to reduce the assessment burden, reflect subject developments, and provide better progression from the new key stage 4 programme of study. A formal consultation on the revised draft criteria was conducted during April 2006 and revised criteria will be published in June. New GCE specifications will be submitted for accreditation in April 2007 for first teaching in September 2008.

*June 2006*

## LIST OF RESOURCES

1	Student Review of the Science Curriculum—Major Findings	Planet Science/Institute of Education/ Science Museum	2003
*2	21st Century Science GCSE Pilot Development— Final Report	The University of York Science Education Group	2003
*3	QCA Key Stage 4 Curriculum Models Project— Final Report	The University of York Science Education Group	2001
*4	QCA Key Stage 4 Curriculum Models Project— Interim Report	The University of York Science Education Group	2001
*5	Developing Assessment Methods—Keeping National Curriculum Science in Step with the Changing World of the 21st Century—Final Report	King's College London and the University of Southampton	2001
*6	Keeping National Curriculum Science in Step with the Changing World of the 21st Century: Working Description and Exemplification of “Scientific Literacy”—Final Report	University of Leeds,	2001
*7	Keeping School Science in Step with the Changing World: A Review of Arguments and Evidence	Kings College London	2001
*8	Keeping the National Curriculum Science in step with the changing world of the 21st century	The University of Liverpool	2001
9	Beyond 2000	Nuffield Foundation	1998
10	Summary of the Key Findings from the 2001–02 National Curriculum and Post-16 Science Monitoring Exercise	QCA	2002
11	Science—2001–02 annual report on curriculum and assessment	QCA	2002
12	Science—2002–03 annual report on curriculum and assessment	QCA	2003
13	Science—2003–04 annual report on curriculum and assessment	QCA	2004
14	Science—2004–05 annual report on curriculum and assessment	QCA	2005
15	Key Stage 4 Programme of study from 2006	QCA	2004
16	Key Stages 1 to 4 Programme of study	QCA	2000
17	Draft Key Stage 3 Programme of study from 2008	QCA	2006
18	Draft GCE in sciences criteria from 2008	QCA	2006



19	Current GCE in Chemistry, Physics, Biology, Psychology criteria	QCA	1999
20	The KS4 story	QCA	2005
21	GCSE Science specifications 2006—Plus summaries		2006

\* Commissioned by QCA.

### Memorandum by RCUK

Research Councils UK (RCUK) is a strategic partnership through which the UK's eight Research Councils work together to champion the research, training and innovation they support.

#### 1. THE CURRENT SITUATION

1.1 RCUK is concerned about the number of students who choose to study biology, physics, chemistry and mathematics in post-compulsory education in the UK. This has the potential to impact upon the UK economy's effectiveness within an increasingly competitive global market<sup>67</sup>, and has a clear potential impact on the ability of the Research Councils to continue to carry out world-leading scientific research.

1.2 However, the decline in the numbers of students studying these subjects is a very complex process which is not accessible to simple solutions. In particular, the factors affecting students' choice of subject at 14 and 16 are numerous, and their interactions are not well-understood<sup>68</sup>. Furthermore, attempts to reverse declining numbers should be seen within the international context, which is that there appears to be a comparable decline in almost every country in the post-industrial developed world<sup>69</sup>. However we note that the process does not appear to be affecting all subjects within science equally<sup>70</sup>, is not affecting all countries equally, and does not affect all regions within countries equally. We believe, therefore, that careful analysis will enable us to learn lessons from these variations.

1.3 We note that the number of students taking biology post-16 has increased significantly over the last 20 years, that the number taking chemistry has remained broadly stable, and that the numbers for physics and maths have decreased significantly<sup>71</sup>. Despite the relatively healthy state of biology uptake, there are significant shortages in technicians within the life sciences<sup>72</sup>.

1.4 The evidence suggests that a significant factor in the decline of student numbers taking physics is the availability of specialist teachers in that subject<sup>73</sup>. Teachers who teach within their specialism are not only those who are most enthusiastic about the subject, but are also those with the confidence to allow students to tackle the questions which they themselves come up with. Although non-subject specialists are able to teach perfectly adequately at all levels, teachers with a thorough grounding in their subject are much more likely to be confident using the full range of pedagogies<sup>74</sup>.

1.5 We believe that a process of fully engaged enquiry, where students both frame the questions, and develop the methods to approach the answers to those questions, is most likely to be exciting and engaging for students<sup>75</sup> and therefore most likely to lead them to want to study a subject at higher levels. It is also the process which is closest to the practice of science as experienced by scientists themselves.

#### 2. THE NUMBER OF SPECIALIST PHYSICS TEACHERS

2.1 The decline in the number of specialist physics teachers is especially concerning, as it has led to an increasing number of physics lessons at all levels being taught by non-specialists<sup>76</sup>.

2.2 This problem is exacerbated at KS3 and KS4, as schools with a shortage of specialist physics teachers will tend to concentrate those teachers' efforts on the upper age groups, where specialist knowledge is perceived to be most important. This may have the unintended consequence of those schools reducing the available pool

<sup>67</sup> HM Treasury (2006) *Science & Innovation Framework 2004-2014: next steps*, HMSO.

<sup>68</sup> Cleaves A. (2005) *The Formation of Science Choices in Secondary School*. Int. J. Sci. Educ., 18 March 2005, Vol. 27, No. 4, 471–486.

<sup>69</sup> Gilbert, J. (ed) (2006) *Science Education in Schools: Issues, evidence and proposals*, TLRP: London.

<sup>70</sup> DfES (2006) *Review of School Science* presentation to the Royal Society seminar "Improving the supply of scientists" 13 June 2006.

<sup>71</sup> DfES *ibid*.

<sup>72</sup> ABPI (2005) *Sustaining the Skills Pipeline*.

<sup>73</sup> Wood, J. & Morris, A. (2005) *Report of the Working Group on Physical Science and Maths Education*, NERF.

<sup>74</sup> Woolnough, B. (ed) (1994) *Effective Science Teaching*, Open University Press, Buckingham.

<sup>75</sup> Gilbert, J. *ibid*.

<sup>76</sup> Smithers, A., & Robinson, P. (2005) *Physics in Schools and Colleges. Teacher Deployment and Student Outcomes*, Gatsby Foundation/ University of Buckingham.

of students capable of entering post-16 science study, as it inevitably leads to an even larger proportion of lessons for younger age groups being taught by non-specialists. It is our view that this is a significant problem, as non-specialist teachers' lessons are likely to be less engaging for the students involved (see 1.3)<sup>77</sup>.

2.3 We note the DfES targets laid out in "Science & Innovation Framework 2004–2014: Next steps", and we welcome these as being a significant step towards redressing the balance of specialist physics teachers. However, we note that the majority of PGCE courses which might train such teachers are for "Science" rather than for "Physics", "Chemistry" etc, and therefore progress towards these targets may be difficult to track at the level of trainee teachers<sup>78</sup>.

2.4 We note that the targets laid out in "Science and Innovation Framework 2004–2014: Next Steps" are extremely challenging, and that in order to achieve them it will not be sufficient to rely on the supply of new graduates entering PGCE courses. However, we believe that in addition it will be necessary to retrain those who have a physics qualification who are already in the workforce. The retraining of those who are specialist teachers in another branch of science (in particular, biology), who might be given a more thorough understanding of physics whilst already having the requisite pedagogical knowledge, may also be a productive way forward.

2.5 We also note that the age profile for physics teachers is significantly older than that for teachers of the other sciences and maths, and we believe that this demographic issue places an added importance on the efforts to increase the supply of specialist physics teachers in schools<sup>79</sup>.

### 3. NEW GCSE SPECIFICATIONS

3.1 We welcome the new specifications for GCSE in England, as we believe that they will go some way to enabling teachers to take ownership of their subject. The previous specifications were too detailed, leading to science teachers feeling too often that they were a de-professionalised cadre of "content deliverers". The new specifications will free teachers to some extent, enabling them to use their professional expertise to develop engaging activities for their students. At the same time, the emphasis on "How Science Works", will mean that those activities will be linked to the realities of science as it happens in the modern world. We believe that this "re-professionalisation" of science teachers will have a positive effect on their retention, and on the levels of engagement of their pupils.

3.2 However, it is only by using the full range of pedagogical approaches that teachers can give their students a good understanding of "How Science Works"<sup>80</sup>, and therefore (as noted in 2.2) the issue of teachers who are subject specialists is a particularly important one in this regard.

3.3 Similarly, it is crucial that changes in the curriculum in England and Wales are mirrored by changes in the summative assessment regime of the various awarding bodies. Unless this occurs, teachers will not have the confidence to embrace unfamiliar styles of teaching<sup>81</sup>.

### 4. PROFESSIONAL SUPPORT FOR TEACHERS

4.1 Continuing professional development (CPD) for science teachers needs to have the same pedagogical content as that for teachers of other subjects. However, we believe that the nature of science means that there is an additional requirement, not relevant to other subjects, which is that science teachers' CPD also needs to keep them up-to-date on new developments in the field<sup>81</sup>.

4.2 RCUK have collaborated with the Regional and National Science Learning Centres (SLCs) to pilot a range of "Science Update" courses, enabling cutting edge scientists to bring science teachers into contact with the most recent developments in the field. Early indications suggest that these courses are very popular. We note that SLCs report that it is often difficult for teachers to be released by their Senior Management Teams for courses other than those with specific pedagogical content. The pilot courses described above have partly avoided this problem by providing resources to pay for the schools' supply cover.

4.3 A full evaluation will be published in September 2006 to determine the extent to which these courses are a valuable addition to those run by the SLCs. If the provision of resources to pay for supply cover is found to be a significant factor in the success of these courses then this will have significant implications for the future schemes of this type.

<sup>77</sup> Woolnough, B. (ed) (1994) *ibid*.

<sup>78</sup> Smithers, A., & Robinson, P. (2004) *Teacher Turnover, Wastage & Destinations* DfES, London.

<sup>79</sup> Smithers, A., & Robinson, P. (2004) *ibid*.

<sup>80</sup> Bartholomew, H., Osborne, J. F. & Ratcliffe, M. (2002) *Teaching students "ideas-about-science": case studies from the classroom*. Paper presented at the Annual Conference of the National Association for Research in Science Teaching (NARST) New Orleans, April.

<sup>81</sup> Gilbert, J. *ibid*.

## 5. CURRICULUM ENRICHMENT ACTIVITIES

5.1 RCUK are involved in a number of schemes designed to generate enthusiasm in both science teachers and students. We run the Researchers in Residence scheme, which provides UK schools with access to young, positive role-models in the physical, social, life and earth sciences and the humanities, who work alongside teachers and pupils in the classroom. By doing so, it meets its twin aims of engaging pupils with contemporary research, and providing opportunities for early-stage researchers to develop and use their communication skills. We are a major sponsor of the British Association for the Advancement of Science's CREST Awards, which encourage students to undertake their own research: enabling them to undertake research projects where they frame the questions, develop the methods, and uncover the answers at their own pace and for their own purposes. We are a significant supporter of the Nuffield Foundations Science Bursary Scheme, providing financial and in-kind support to students undertaking placements lasting 4–6 weeks, during which they undertake a self-contained research project in a research institution. We are also involved in the Science and Engineering Ambassadors Scheme, and numerous other smaller initiatives.

5.2 Our involvement in these schemes is based upon the belief, which has been substantiated by successive reports and evaluations<sup>82, 83, 84</sup>, that they play a significant role in engaging students with science as a living subject. The schemes all have at their heart the understanding that the thing which is most engaging for students, whether at primary, secondary, undergraduate or postgraduate level, is the process of research: the framing of questions, the development of methods, the overcoming of difficulties, and the uncovering of satisfactory answers.

5.3 At the same time, they recognise that “science” is much more than what happens in school science labs<sup>85</sup>. The recent DfES consultation on “Education outside the Classroom”<sup>86</sup> had this as a central issue, and we welcome the fact that the concept of good science teaching is being extended beyond what is possible within walls of the science lab.

June 2006

### Memorandum by the Royal Academy of Engineering

1. A principal objective of the Academy (Note 1) has long been to attract and to encourage the most able students in science, engineering and technology (SET) subjects to fulfil their potential in these subjects and ultimately enter the engineering profession.
2. The Academy believes that it is of prime importance to ensure that schools continue to provide sufficient students in both quality and quantity required to meet the national need for engineers, scientists, mathematicians and technologists in order for the UK to sustain a world-class, global competitive economy. This is highlighted by the recent Report *Educating Engineers for the 21st Century—The Industry View (March 2006)*, commissioned by the Academy from Henley Management College, and the Academy's Commentary ([www.raeng.org.uk/henleyreport](http://www.raeng.org.uk/henleyreport)).
3. To this end, the Academy has supported schools and colleges through its Best Programme (Note 2). It is now expanding its activities through the provision of industry based CPD for teachers, in collaboration with the National Education Business Partnership Network (NEBPN) and the National and Regional Science Learning Centres. At the same time, the Academy is now also working to widen access to the engineering profession by developing new routes through all types of schools and colleges in its Technology and Engineering in Schools Strategy (TESS) (Note 3) and in establishing the London Engineering Project (LEP) as a demonstrator programme for the proposed National Engineering Programme (NEP) (Note 4).
4. The Academy activities thus directly support the *Science and Innovation Investment Framework 2004–2014: Next Steps* recommendations for improving the supply of scientists (Chapter 6): in particular at achieving a step change in the quality of science teachers and lecturers in every school and college (paragraph 6.5) through support for the Continuing Professional Development (CPD) of Science Teachers (in conjunction with the Science Learning Centres) (paragraph 6.8) in order to improve the quality of science lessons (paragraphs 6.22–6.23) and improve career advice (paragraph 6.26). However, its major resources in the Best Programme

<sup>82</sup> Woodfield, K., Ritchie, J. & Clayden, M. (1999) “*They all wear white coats don't they?*” *Challenging stereotypes and promoting science in schools: an evaluation of the Researchers in Residence Biosciences scheme* The Wellcome Trust: London.

<sup>83</sup> Smithers, A. & Robinson, P. (2002) *PRI and the positioning of the Research Councils in Schools Science Education* University of Liverpool.

<sup>84</sup> Barstow, M. (2005) *Bringing Space into Schools Science* PPARC: Swindon.

<sup>85</sup> Gilbert, J. *ibid.*

<sup>86</sup> [www.dfes.gov.uk/consultations](http://www.dfes.gov.uk/consultations)

and the London Engineering Project are directed towards the students themselves, in order to increase the progression to higher courses in SET through A levels and applied learning courses (paragraphs 6.24–6.25).

5. From the experience gained in these initiatives, the Academy advises the Committee as follows.

#### THE CURRENT SITUATION

6. There is a paramount requirement for integrated policies and processes from primary school to university. Currently, the Academy shares the Committee concern that there continues to be widespread evidence that schools are failing to attract sufficient students to take mathematics and science subjects (particularly physics) to A level. Equally important is the support of students following applied learning courses supporting the new Diploma courses, Advanced Apprenticeships and entry to Foundation degree courses.

7. As submitted in our response to the House of Commons Science and Technology Committee Inquiry on *Science Education from 14–19* (January 2002), it is essential to ensure an adequate supply of high quality engineering and science graduates. Many of the problems inherited by the universities in the poor competence of students in mathematics and physics have their origins in the inadequate level of mathematics and physics teaching in many schools. It is essential that a sufficient number of good, appropriately qualified teachers in mathematics, science and technology are trained, supported and motivated so as not only to retain them in the profession but also to encourage and stimulate their students to take up science, engineering and technology (SET) careers. The situation is particularly acute in physics teaching. There is some evidence that action taken at that time to increase the provision for physics teacher training is having effect. Nevertheless, it is estimated that the physics teacher training output needs to be raised from the current 450 to 750 a year to replace the teachers retiring, and otherwise leaving, and so enable schools during the next five years to have the prospect of at least a quarter of their teachers of physics being qualified in the subject. The Academy wishes to draw the Committee's attention to the recent study on *Physics in Schools and Colleges* (Alan Smithers and Pamela Robinson, Centre for Education and Employment Research, University of Buckingham November 2005 [www.buckingham.ac.uk](http://www.buckingham.ac.uk)) which considers these issues in depth.

#### ATTRACTING SCIENCE TEACHERS

8. The Academy has no direct experience in this area but notes the recommendations for improving physics teacher recruitment in 6.21 of *Physics in Schools and Colleges* report concerning more money, teacher status, better technician support, sabbaticals and recognising the affinity between physics and mathematics.

#### TEACHING SCIENCE

##### *Professional Support for Science Teachers*

9. Having trained the teachers, it is essential that they are stimulated, motivated and supported through appropriate continuing professional development (CPD). The establishment of the National and Regional Science Learning Centres (SLCs) has laid the foundations for providing a more sustained and comprehensive framework of CPD provision for teachers.

10. The Academy sees this as a new opportunity to work with the SLCs to make teachers more aware of the application of science in engineering and technology enterprise and the careers these sectors offer to their pupils. This will help them enrich their delivery of the core curriculum by inclusion of material illustrating the technological impact of science and enable them to give informed careers advice on the wide range of exciting and rewarding careers accessible to students in the SET sectors. In 2006–07 a series of one day industry placement CPD courses for 750 science teachers is being arranged through the NEBPN with a view to making such course permanently available as accredited CPD.

11. The Headstart Programme (a university based course in University Departments of Engineering to give hands on experience of engineering projects and awareness of the careers available) is also being adapted for teachers and is currently being piloted.

##### *The impact of existing schemes designed to help generate enthusiasm in young people for science subjects*

12. The Academy leads the Best Programme: a suite of programmes in SET curriculum enhancement schemes (Note 2). The Best Programme works in primary schools to build an enthusiasm for SET subjects, in secondary schools to promote engineering and related SET careers, in universities to support gifted engineering students and beyond university to develop engineers in their careers.

13. Best is already making a significant impact with over 1,300 Young Engineers Clubs established in schools. Through the Smallpeice Trust and the Engineering Education Scheme over 3000 (mostly Year 12) students gain direct experience of working with industry and studying in university engineering departments each year and a further 800 students attend one week induction courses in SET subjects in 26 universities through the Headstart Programme. A further 700 students take a gap year in industry through the Year in Industry scheme. The schemes are proving successful in attracting women into SET with attendances of 30–40%. Evidence from the Headstart and Engineering Education Schemes show that generally over 75% of attendees proceed to take SET degree courses.
14. The Academy measures the impact of the Best Programme in two ways. With schemes for younger students, engaging more young people with the world of engineering is key. With older students, particularly 16–19 year-olds where decisions on A levels and other study choices have already been made, success is retaining those with an interest in engineering as much as it is persuading more people to choose engineering in the first place.
15. Measuring the impact of individual schemes is notoriously difficult, particularly for schemes involving very young people who won't enter engineering employment for many years. The Academy has commissioned some independent impact assessments of the schemes involving older participants. The Engineering Education Scheme was found to create an appreciable number of fresh engineers (around 100 each year) and was able to retain the enthusiasm for a life in engineering amongst a good deal more of the 1,800 participants each year.
16. It is highly significant that 75% of participants in the Year in Industry scheme remain within the engineering sector on graduation.

## SCHOOLS

### *Links between schools, universities and industry, to facilitate science teaching*

17. The importance of education enrichment in science teaching cannot be over stressed. Building on the success of the Best Programme, the Academy is now extending these initiatives across the whole engineering sector through TESS and the National Engineering Programme. The ultimate aim is to ensure that enrichment is accessible to every student in every school.
18. The TESS mission is to give every primary and secondary school in the UK, regardless of geography or local circumstances, equal access to a good number of quality-approved, high impact, co-ordinated schemes in engineering and technology related education. This will be achieved by the co-ordination of existing national-scale engineering and technology education schemes that deliver curriculum enrichment and/or teacher CPD. It will cover the promotion of engineering, the provision of information and the delivery of educational enrichment activities in engineering and technology to young people.
19. The Academy leads the National Engineering Programme, a consortium effort to strengthen engineering higher education by working with universities to create inspiring, attractive engineering degree courses, and then working with local FE colleges and schools to provide candidates for those courses.
20. Industry has a strong role to play: on one hand they co-fund the programme along with government, on the other hand they are able to go into schools and assure students that there is good employment on offer after graduation.
21. This model of co-operative working has proven effective in raising the profile of engineering (and the wider SET curriculum) in schools where it has not been a priority in the past. Particular attention is being paid to groups so far underrepresented in engineering higher education: women, minority ethnic students, students from families with no experience of higher education and adult learners.
22. The National Engineering Programme supports schools with their raised profile for SET by providing students with access to hands-on SET activities in class, residential and other SET learning events out of school and a system for mentoring of students with a capacity for higher education and ability in SET.
23. This attention paid on schools and groups so-far unengaged in engineering is seen as key to strengthening the engineering profession in the long-term.

*June 2006*

## NOTES

1. The Royal Academy of Engineering [RAEng] brings together over 1,200 distinguished engineers, drawn from all the engineering disciplines. Its aim is to promote excellence in engineering for the benefit of the people of the United Kingdom. ([www.raeng.org.uk](http://www.raeng.org.uk))
2. The Best Programme provides support to over 80,000 students in science, engineering and technology for age 9 to 36 years. ([www.raengbest.org.uk](http://www.raengbest.org.uk)).
3. The Technology and Engineering in Schools Strategy (TESS) was initiated by Lord Sainsbury of Turville in 2005 and is a programme through which the engineering community has agreed to work together to provide better co-ordinated support for the promotion of engineering and technology in schools.  
It is led by the Royal Academy of Engineering and involves the engineering institutions and other bodies active in promoting engineering and technology to schools at a national level. Membership currently comprises: the Royal Academy of Engineering, the Office of Science and Innovation, the G15 of Engineering Institutions, the Engineering and Technology Board, SETNET, the British Association (BA), the Institute of Physics, the Association of Science Educators and the Learning Grid.
4. The NEP started with the London Engineering Project pilot in Southwark in late 2005. This will work with five universities and 50 schools over 4.5 years. The pattern will be repeated, modified and enhanced, as appropriate, in six regions in England over the 10 years.  
The NEP is led by the Royal Academy of Engineering with the generous support of the Higher Education Funding Council for England (HEFCE).

#### **Memorandum by Royal Armouries HM Tower of London**

1. As one of the many Science teachers who has recently left mainstream teaching I am not unusual, but as one who has found a way to remain within Science Education, but without the constraints of a classroom I feel well able to comment on one of the ways that we in the museum and heritage sector have to support science colleagues back in school.
2. In 2003, as part of an important new initiative designed to enable children to take a completely new look at their national museum, the Royal Armouries created a Materials Science post at the Tower of London. I am that Science Education Officer and as Science certainly isn't the first thing you think of when you think of HM Tower of London making my museum collections relevant to the Key Stage 3 Science National Curriculum and subsequent development of sessions has certainly been challenging! However we have succeeded here, even with the constraints of the National Curriculum thrust upon them as well as the need for these sessions to be relevant to the site or collections -some sessions now are straight from the curriculum! As a result I do feel that most museum collections can be linked to some elements of the Science curriculum so long as you are prepared to think "out of the box". By involving our museums and heritage sites, all of whom have a unique collection of resources and expertise, we can find ways of delivering the Science curriculum without overburdening teachers. This is indeed in keeping with current DCMS policy.
3. Currently our secondary science sessions involve all strands of the National Curriculum and as bringing Science to life in such an amazing setting is the easy part we are well on the way to making our audiences think that the Tower is even more than the acclaimed World Heritage site that it is! We consider the science in everyday (or even yesteryear) applications. Whether considering our famous prisoner, Walter Raleigh-Tudor Prisoner and Scientist, when we look at separating techniques or looking at Armour as evidence using animals body protection and the development of materials as its focus or carrying out a forces investigation Bow or Arrow-choose your wood I can guarantee that sufficient elements of the curriculum are covered that would not only justify the Science teachers bringing out their pupils but also bring some of the awe and wonderment back into the subject. We even have a forensic session based around a Murder at the Tower.

*June 2006*

#### **Memorandum by the Royal Astronomical Society**

1. The Royal Astronomical Society (RAS) represents astronomers and geophysicists, some of whom are teachers, others support school activities. The RAS Education Committee is responding to this call for evidence, and our response will focus on the questions related to our specialist areas.
2. The RAS welcomes the higher profile of astronomy in the English national curriculum (and the new GCSE specification) as an excellent way of engaging young people in science. Scotland already bases much of its science teaching through the flagship topic of Space and the Scottish Space School engages with around 3,000

pupils each year (aged between five and 18). Scotland also has an environmental science curriculum (KS2 and KS3) which touches on many topics in geophysics (such as volcanoes, earthquakes, continental drift, the earth's core, climate change). Astronomy, Space Science, Geophysics not only encourage young people to take up science because they find it exciting and mind-stretching, it sustains their interest over many years leading them to pursue a career in science and also motivates them to become teachers of science. It is forever new and challenging. Many young people have decided whether they are interested in science or not, before they reach secondary school, so that although the present concern may be to get more young people to study science at A-level, the problem must be tackled from Key Stage 2 (KS2) onwards with consistency, dedication and cash.

#### THE CURRENT SITUATION

3. The RAS does not have figures on the retention levels of science teachers at KS3 and KS4, but anecdotally amongst Fellows we find that science teachers at this level do not feel valued (either in terms of salary or respect in the community). Many enterprises have support schemes (such as mentoring) for graduate recruits, there should be similar active programmes for young teachers; most authorities have these in place but we are not certain how effective they are. There is a big problem being a "Science Teacher" in a secondary school for KS3 and KS4; people who have a PhD in physics or maths are good at physics and maths, but they can find it difficult to teach biology or chemistry since they have no knowledge of those subjects (and consequently may not be very good at it), and vice versa with biology and chemistry graduates. By analogy teachers of French are not expected to teach Dutch even though they are both "European languages". Science subjects should be taught by people specialising in that subject. Whereas teachers teaching inside their specialist area can often inspire young people into considering a career in science, when teachers are non-expert (or worse not interested) in the science subject they have to teach, it can completely turn-off the young person ("You are not teaching A-level X next year, are you Sir??")

#### ATTRACTING SCIENCE TEACHERS

4. Although many pupils may realise that a course in astronomy or even space science is possible at university, many pupils are not even aware the "geophysics" exists as a discipline (and that training in physics is necessary), and so numbers for geophysics course at university are dropping (British Geophysical Association review of geophysics education in the UK). Significantly more places are being made available for scientists to undertake a PhD in astronomy, with no more funding provided for posts after that. Up to 50% of astronomers with a PhD can find a post-doc position for three years, but then it becomes increasingly difficult to stay in the astronomy-research field. This gives rise to a pool of potential science teachers, but the RAS sees no attempt being made to exploit this opportunity. The RAS organises "career sessions" for young astronomers at the annual National Astronomy Meeting, and the young scientists do not regard teaching as a post-PhD career. In the RAS "Careers in Astronomy" study, we make the point that astronomy graduates should be recruited to teach astronomy in school, as physicists are recruited to teach physics etc. There should be active recruitment campaigns at events like the National Astronomy Meeting, UK Solar Physics Meeting, British Geophysical Association meetings, etc, to encourage young scientists to become teachers.

5. Schemes such as the Undergraduate Ambassadors and Science and Engineering Ambassadors introduce people to schools and the modern curriculum, so that seeds can be planted that teaching can be an exciting and rewarding profession. Are any attempts made to encourage the seeds to grow, perhaps by extending the schemes to classroom assistant level and through mentoring schemes?

6. The RAS welcomes the higher profile of astronomy in the national curriculum, and would like to see greater availability of additional training for science teachers. Science Learning Centres do run a wide range of courses, including some which focus on astronomy/space and topics in geophysics, but there are problems for teachers wishing to take up the opportunity (see paragraph 12). In today's culture of suing for every problem, teachers need extra training and financial back-up particularly in the area of science where "risky" activities such as experiments or visits are undertaken.

#### TEACHING SCIENCE

7. Why do young people not consider a career in science? Astronomy is a science which many young people find exciting. Their enthusiasm should be exploited from primary school (KS2) onwards, so that by KS3 they have a long-standing interest not only in the astronomy but in the underlying physics and maths. Similarly with topics in geophysics (as reported in the British Geophysical Association review of geophysics education in the UK), meteorology, oceanography, the practical application of physics to modern issues such as planetary resources, climate change, weather, engage young people more than the traditional approaches to the subject.

Most young people have no idea what a scientist actually does, apart from possibly doctors, vets, and more recently forensic scientists (from television dramas and documentaries). Visits by young people to places, and work experience opportunities in places, where science is done are essential—for them to see scientists in “their natural habitats” doing their jobs. In the South East there are science-related places to visit, but some regions have few opportunities. If young people see teachers who are not enjoying the subject they teach, they will have no desire to go into teaching themselves.

8. It is very difficult to take young people out of school for a day, due to the intensive curriculum, the cost, the risk of accident, and the reluctance of venues to support visits (they have little free time, and money, to make the venue “safe” and to provide speakers and demonstrators). Good venues do risk assessments before allowing schools to visit, and schools increasingly ask to see them. Post-SATS at KS3 is a popular time for visits, but these can be expensive since coaches must be hired. For an independent school this is not a problem, but it is a real barrier for some state schools. For A-level students it can be easier, since a minibus is the more usual type of transport needed. (It is often easier to take children from primary schools for a visit to a science venue, and these visits can have a profound, long-term impact.)

9. Since astronomy is frequently undertaken using computers at large telescopes, the Bradford Robotic Telescope (BRT) closely mimics the real experience of observing, whilst avoiding the need to provide and staff the laboratory/observatory. This is an excellent example of what can be achieved to raise the enthusiasm of young people for science. The BRT complements the Faulkes and Liverpool robotic telescopes, which are more suited to special astronomy projects in schools and local Astronomical Societies. Access to the BRT is via an extensive web-site, giving young people and their teachers a taste of the real world of experimentation. It is designed to meet learning outcomes in the English national curriculum for students from 10 to 16 years old (KS2, KS3 and KS4). Being web-based means there is no practical limit to the number of schools on-line at one time. For KS2, the wide-field applications are important, allowing young people to see the constellations (which may be new for them due to light pollution in cities), the Moon and the planets. As they progress to KS3 and KS4, the projects develop, leading the students onto the Faulkes and Liverpool telescopes for advanced projects. (See appendix A for more information on BRT). This approach of web-based practical learning could be extended to other areas; Drax power station and Shell Moss Moran gas plant are under consideration.

10. Another option to support teachers is to produce material jointly, with scientists and teachers working together. CCLRC produced a CD and supporting website “seeingscience” with modules which addressed KS3 learning outcomes using astronomy and space science together with other science modules. This was funded by CCLRC itself with no outside funding. The project was produced with CCLRC scientists and LEA KS3 advisors, so that it was firmly curriculum based and was produced in a form ready for teachers to use. So far 11,000 copies of the CD have been mailed out to schools in the UK (and abroad) in response to requests from teachers (there has been no direct mail-shot), and “School Science Review” said that the CD was “worth its weight in gold”. (See appendix B for more information) Members of CCLRC staff started to produce a companion CD for KS4, but the funding (£130K was needed) from CCLRC’s resources was cut.

11. The Science and Engineering Ambassador scheme is an example of good practice, where scientists are given training, CRB clearance and insurance cover so they can visit schools. Many young people are naturally very interested in astronomy, space science and geophysics topics, which is a challenge for the teachers who are hard-pressed to keep up with the core curriculum needs. The RAS maintains a list of astronomers who will visit schools (through the Association of Astronomy Education), and other groups such as the Institute of Physics also maintain lists. Support of this work, and funding, would enable the people on the list to participate more often and enable the parent organisations to keep the lists up to date. The teachers contacting lists like this are often the teachers with no contacts or support of their own but with enough enthusiasm, or desperation, to search out resources.

12. Professional support for teachers is available, but who will pay? The RAS Education Committee investigated the possibility of training teachers to use robotic telescopes (the Faulkes telescope was used as an example), and the cost of taking 100 teachers out of school for one day (in four venues) and providing professional astronomer support (on an expenses-only basis) was prohibitive. The BRT has put resources into using the telescope in the Initial Teacher Training programmes and extensively uses the web to train the teachers, thus avoiding this problem. Most teachers are allowed only a few days a year for CPD, so this time tends to be used for the essential skills such as assessment, new GCSE topics and teaching-related courses. The school naturally asks what benefit is received by it, and for a science teacher to take a science-based course which is used for a few lessons, this is not cost effective. When a science teacher is away for the day, the school will have to pay up to £160 for a supply teacher, assuming there is a supply teacher available to teach science. If teachers want to extend their knowledge, especially by taking courses in geophysics or space science topics,



this would be an even more serious problem, both for the school and for the teacher finding an appropriate course (at a suitable time). The BNSC partnership report “Bringing space into school science” suggested that bursaries would be needed.

*June 2006*

#### DOCUMENTS USED IN THIS RESPONSE

“The PhD and Careers in Astronomy in the UK”: A report from the Royal Astronomical Society (available on-line at

[http://www.ras.org.uk/images/stories/ras\\_pdfs/careers\\_in\\_astronomy.pdf](http://www.ras.org.uk/images/stories/ras_pdfs/careers_in_astronomy.pdf))

“Geophysics Education in the UK”: A Review by The British Geophysical Association (draft)

“Bringing Space into School Science”: A report commissioned by the British National Space Centre partnership (available on-line at: <http://www.pparc.ac.uk/ed/barstow.pdf>)

### APPENDIX A

#### CONTRIBUTION TO THE RAS RESPONSE TO: THE HOUSE OF LORDS SCIENCE AND TECHNOLOGY COMMITTEE: LOOKING AT SCIENCE TEACHING IN SCHOOLS: MAY/JUNE 2006 JOHN BARUCH—UNIVERSITY OF BRADFORD

#### SUMMARY

1. The UK Robotic Telescopes can play a unique role in inspiring young people and their teachers with science.
2. The UK robotic telescopes provide access to a range of practical science experiences providing an effective alternative to no laboratory experience in their National Curriculum studies.
3. The Bradford Robotic telescope (BRT) has shown that it can support primary school teachers and deliver inspirational practical science to all school students at Key Stage 2, continuing through the science turn-off years to KS4.
4. The Faulkes and Liverpool telescopes can inspire a significant fraction of the school student secondary science cohort especially in the sixth form reinforcing their interests in the STEM areas.

#### BACKGROUND

The UK has benefited from a unique programme of robotic telescope development for education. There have been three major developments: The Liverpool Telescope, the Faulkes Telescopes and the Bradford Robotic Telescope within a world scene of around 200 robotic telescopes. The Faulkes and Liverpool telescopes are research instruments with an educational slant. They have a field on the sky of about one sixth the diameter of the Moon or five arc minutes, typical of a research instrument. The Bradford telescope is designed to support basic astronomy education especially the practical aspects and includes a research slant. It has five cameras recording aspects of the night sky, including broad panoramas of the constellations, deep sky cameras for galaxies, and night time web cameras to follow the stars setting over Mount Teide and rotating around the pole star.

These robotic telescopes are inspirational in the classroom. One explanation of the electricity that they create for learners is that it takes the students into the world outside the classroom where they can request their own data from real world facilities to support their own learning programmes. When the data is delivered to them they process it themselves to extract their learning. This process more closely reflects their developing understanding of the world, with extensive input from the Internet and television supplementing the views of teachers and parents.

#### A NEW FORM OF LABORATORY EXPERIENCE

The Faulkes and Liverpool telescopes allow the students to actually drive the telescope in half hour slots. The students plan their observing and execute it to obtain the data which they then process. In this way it provides superb practical experience but with only about two half hour slots per lesson the practical experience is limited to a very small number of students. The Bradford Robotic Telescope operates in a service mode and

observations are requested by the students. In the normal course of events the data will be returned to the student for the next lesson. Each student will then have their own data for processing and to develop their learning. The telescope can support every student in the class doing this and in 1,000 classes besides. The secret is that most students' knowledge of the sky is limited to 25 or so objects which the telescope can process in half an hour. This is the benefit of delivering the basic levels of understanding. The simplest of research programmes may consider thousands of objects to observe and so the number of students using the system will be severely constrained.

Using robotic telescopes is inspirational in the classroom. This appears to be because the students are being serviced by a real robot operating in the outside world that also services other students and real astronomers in their research.

All three telescope systems can be used by a whole class either to drive the telescope or to submit an observing request.

There are indications that the Bradford Robotic Telescope experience can be expanded to cover major sections of the science part of the National Curriculum with developments being initiated with a number of partners to give school students real time web access to the systems at Drax power station and the Shell Moss Moran gas plant.

### THREE UK ROBOTIC SYSTEMS?

Whilst Faulkes and Liverpool systems focus on the telescope, the Bradford system focuses on the teachers' concern for delivering the national curriculum and provides in-depth support for the teacher. The Bradford system is essentially an extensive web site focussed on the National Curriculum for England and Wales which is supported by the robotic telescope providing a practical avenue to support learning and understanding.

The Faulkes telescope provides slots for classes to control the telescope and so is limited to a tiny fraction of the UK students, the Liverpool telescope is essentially a research telescope which devotes 5% of its time to education, The Bradford system can support all the children in the UK. The way in which all three systems associate research with education is inspirational in the classroom.

All robotic telescopes in the world apart from the Bradford and Liverpool systems are designed to be driven remotely. This means that the user has a half hour slot which is easily wasted if the user is not an experienced driver or the weather is adverse. Even with the best conditions remotely driven telescopes can only support around 1,000 users per year. The Bradford and Liverpool telescopes are completely autonomous robots which work much quicker, can merge identical requests with single observations and schedule observing at the optimum time.

Only the Bradford system is dedicated to providing understanding at the most basic levels. Experience over years of development has shown them that they can support the education of all school children in the UK. The Liverpool telescope goes beyond the basics and so the number of different objects that are requested grows with the number of users. This provides a clear cap on the number of users which again is less than a 1,000 per year.

Together these telescopes can inspire all UK School students with the STEM subjects. At the basic levels the Bradford Robotic Telescope can deliver practical observations to all school students in the UK. The Faulkes and Liverpool telescopes can maintain that inspiration into A level and specialist astronomy groups in years 12 and 13.

### TELESCOPE FUNDING

The Faulkes telescopes are funded by an American philanthropist as a global service to school children. As such their funding appears secure. The Liverpool telescope is part of the suite of telescopes available to UK astronomers with support from a Canadian philanthropist and 40% of the costs supported by PPARC. The Bradford telescope was initiated as a pilot programme and it is nearing the end of its development. The plan was to switch off the BRT in the summer 2006. The group has been lobbied extensively with the case that to switch it off and disperse the team would be a serious loss to UK education which leads the world in this area. A programme to generate a sustainable funding model and immediate funds was launched in autumn 2005. Funds are required to provide a robust system responsive to the demands of a million or more UK users and to pump prime sustainable operations.

## FACTS ON BRT

The Bradford Robotic Telescope now has around 7,000 users, more than 500 of these are teachers who have logged in over 2,500 of their students to work in class groups. Quite a number of the teachers are still experimenting with the system and have yet to log in a class group.

The system is effectively a large web site devoted to the teaching of the astronomy sections of the National Curriculum from ages 10 to 16 which is supported by a robotic telescope. We can confirm that much of science is taught by teachers who are working outside their areas of expertise; typically in secondary education biologists teaching astronomy. In primary education the situation is much worse with many of the teachers having no science at all.

*John Baruch*

*31 May 2006*

## APPENDIX B

## CONTRIBUTION TO THE RAS RESPONSE TO THE HOUSE OF LORDS SCIENCE AND TECHNOLOGY COMMITTEE: SCIENCE TEACHING IN SCHOOLS

**Summary by Dr Helen Walker, CCLRC Rutherford Appleton Laboratory—16 June 2006**

seeingscience CD and web site

Web address: <http://www.seeingscience.cclrc.ac.uk/>

seeingscience is a unique set of interactive science resources for KS3, produced by scientists at CCLRC and LEA KS3 Advisors. The material covers several topics, focussing on the work of the Synchrotron group and Space Science group. The material is free and the CD will be supplied on request. "School Science Review" said that the CD was "worth its weight in gold".

SPACE—This covers the QCA KS3 unit of work 7L "The Solar system and Beyond", through an "ideas and evidence" approach. All lessons include lesson objectives (WALT) and differentiated outcomes (WILF). Suggested starter and plenary activities are included in addition to the main lesson activities.

Our Solar System—covers the Sun, Moon, planets, the orbits of the Earth and the Moon and other planets. A time lapse video of 24-hours at CCLRC Rutherford Appleton Laboratory illustrates day and night, and leads to a discussion about the seasons. Pupils discover what a model can demonstrate and what are the limitations.

Because I said so!—is about history of astronomy and the people who are responsible for our views of astronomy today, using documentary "evidence" from five different types of source; primary sources (postcard and diary) and secondary sources (books, newspapers and the internet). Present day astronomers at CCLRC Rutherford Appleton Laboratory explain what they do and what they hope to find in space.

Mission to Pluto—starts with the criteria used to classify an object as a planet, and whether Pluto meets them. Pupils interactively design their own mission to Pluto within a payload constraint, and explain what evidence their selected instruments would gather.

BRIGHT LIGHT—This section looks at how particles are accelerated in a particle accelerator known as a synchrotron to produce the extremely bright light (X-rays and ultra violet) which is used to determine the structure of many different materials. The synchrotron is a very versatile scientific tool, and it spans many sciences including biology, chemistry, materials, physics, medicine, environment and archeometry.

Life—can anthrax lead to a cure for cancer? Early results from the synchrotron suggest it might. Pupils explore how scientists work to control the outbreak of a disease, and there is a game Outbreak to play.

Food—powerful X-rays from the synchrotron are being used to discover what happens at the atomic level when chocolate is made and what changes take place as chocolate cools. The discoveries are used to "iron out" production line problems. Microbes in food fluoresce under ultra violet light from the synchrotron. Microbe growth is being studied with the aim of producing safer food. Pupils emulate the work of scientists in these two areas.

Materials—how do you decide if the materials you wish to use are suitable for the job, eg the Thames Barrier, the Coliseum? Scientists looked at how different additives could affect the setting properties of cement and the deep penetrating X-rays produced by the synchrotron can reveal the chemical changes taking place. Pupils will make cement samples with different additives and test their strengths.

Environment—using the synchrotron two problems are examined; how to clean up heavily polluted sites and atmospheric pollution caused by sulphur dioxide. The latter gives an opportunity for cross-curriculum links with ICT.

### **Memorandum by the Royal Meteorological Society**

#### 1. PREAMBLE—THE SOCIETY

The Royal Meteorological Society was founded in 1850 and since that time has been the UK Learned Society for meteorology, and closely related sciences. The Society received its Royal Charter in 1866 and is a registered charity. HRH the Prince of Wales is currently the Patron of the Society.

The Society has an international membership with currently around 3,000 members, who include both professionals and interested enthusiasts. Our mission is the advancement of meteorological and related sciences and we provide support and advice to a wide range of interested groups and bodies, including Government.

In delivering this mission, the Society has a very wide portfolio of activities which include:

- An Education programme supporting primary and secondary schools both in the UK and overseas. The Society also runs a popular on-line schools forum for making weather observations and exchanging weather information across the globe (MetLink International, <http://www.metlink.org/index.php>).
- An Accreditation programme that awards chartered status (Chartered Meteorologist, CMet), endorses courses on meteorology and related subjects and administers, on behalf of the Sector, National Vocational Qualifications NVQ/SVQs level 3 and 4.
- An active Meetings and conferences programme on topics of current scientific and popular interest within its disciplines. This programme ranges from detailed and advanced research material to the popular understanding of science and regularly includes joint meetings with other learned societies and organisations.
- The funding of full time MSc scholarships in meteorology and part-time undergraduate vacation employment in the subject.
- The award of prizes for academic excellence.
- Funding of grants to (mainly young) scientists to attend meetings and conferences and to undertake small research projects (often these are school projects for which no other funding sources are available).
- An internationally recognised Publications portfolio that serves the academics, applied meteorology/climatology professionals, and weather enthusiasts. Like many learned societies, the Royal Meteorological Society relies heavily on the income from its publications (some 65% of Society revenue) to fund this wide range of charitable works.

Further information on the Society can be found at <http://www.rmets.org>.

#### 2. EVIDENCE TO THE COMMITTEE

##### 2.1 *Choosing to do science at A level*

###### 2.1.1 The Key Drivers

There seem to be some key drivers that determine whether children set a path towards A level science. These drivers operate at different stages in the progression from KS3 through to the start of the A level studies and relate to different aspects of the learning schedule as it progresses.

###### 2.1.2 Exciting a lifelong interest

The first step on the path to A level science is taken very early in the learning experience and at this stage (KS3 for the purposes of this enquiry) the key issue is exciting interest in the natural world and how it works. Physics, and probably also chemistry, tend later in the education process to be seen by students who have not earlier been engaged by science as rather abstract, difficult subjects not well connected to their everyday world. There is therefore a need to introduce children at an early stage to the fascination of the world around them and the understanding that science is just an explanation of how that world works. This can be done through a

programme of observation and analysis supported by an explanation of the relationship between what children see and record and the working of the wider environment around them. Such activity should be clearly seen by the children as “science” so that the perception that science is exciting, relevant and understandable is one that is implanted early. An effective and, for children, attractive methodology to achieve this is through practical projects which can serve as vehicles for committed, enthusiastic teachers who are able to deliver the necessary explanations.

Learned Societies such as the Royal Meteorological Society, endeavour to provide both the projects and the support for the teachers through programmes such as MetLink International (<http://www.metlink.org/index.php>) and Raincatch (<http://www.raincatch.org>) and publications such as “The Science of Weather—A Primary School Resource”. However, the take-up from state schools of these free opportunities and resources is often disappointingly low. This seems to be because such generic projects, which provide heuristic opportunities across several of the components of the national curriculum, and the particular subject to which they are attached (in these cases weather, climate and the environment) are not explicitly included within that curriculum. The apparent lack of teacher expertise in the basic scientific disciplines such as observation, recording and analysis coupled with a consequential lack of confidence that they can handle “science” at this (or any) level, add to the difficulties of getting children engaged with science and hinder their grasp of the fact that they are actually “doing” science. The resulting dissociation of learning activities from science might, in extreme cases, implant a fear of science as being too difficult and the concept that it is not relevant to them which can persist in the students even for life.

### 2.1.3 Preparing the ground

The “one-size-fits all” approach of the National Curriculum is not in the interest of science and mathematics. Whereas in English, for example, the same assignment can draw work of widely differing standards from a class of students, so that all may be stretched, in maths the standard is determined by the assignment itself, so teaching necessarily proceeds at the speed of the slowest. Science is in between. The standards of GCSE are low in all subjects but the jump to A level matters less in arts subjects where there is no hierarchy of learning. In science and particularly in mathematics these low standards mean that students have to be intrinsically very good or willing to work disproportionately hard to go on successfully to A level. Since schools have a duty to deter students from courses with which they believe the students will not be able to cope, we have a combination of circumstances which clearly militates against the encouragement of science and mathematics at A level.

### 2.1.4 Presenting choices

Students looking forward to university entrance will be strongly motivated by what they perceive to be their best chance of obtaining the necessary A level grades. They are also motivated to take the subjects in which they see the greatest number of attainable university places. Universities are providing many courses in areas such as psychology and sports science so these subjects are seen by students approaching A level as leading on to higher education. This has resulted in a growth of such subjects at A level and in their popularity with students who perceive them to be easier than the traditional sciences and linked more closely to “their world”. It is at this stage that the failure to engage the interest of children in the physical sciences early on and the lack of adequate standards in mathematics and science at GCSE delivers a shortfall in students choosing A level science.

## 3. WHAT CAN BE DONE

The contribution that this Society (and probably others) can make to correcting this situation is to develop vigorously the sort of interactive schools science projects that we are already undertaking to the limit of our present resources (see 2.1.1 above). However this cannot be done without forging a coalition of the willing. And only when teachers see the need for this within the national curriculum and the importance of stimulating scientific excitement can this coalition be forged on a wide front. The Societies could potentially help with the lack of teacher expertise and confidence by providing from their membership volunteer experts who could assist teachers with the technical aspects of the subjects on a short term, project basis. This might be done in a one to one or in a one to many (short course) format but would in either case under present arrangements rely upon volunteer effort and could not be guaranteed to be uniformly available across the nation or through time. It might, however, provide a bridge between the present situation and a future one in which these science foundations are a normal part of professional teacher training for those teaching young children. Most

Societies are quite small centres of knowledge and expertise so that to expand their activities in this way would require additional external resources to manage the projects.

The inclusion of wide ranging science based studies such as “science of the environment” (which could include projects on weather, climate, the sea, rivers, land, energy, pollution etc) in the KS3 to A Level national science curriculum would provide vehicles for the introduction of both the scientific methods and the topics within the science subjects. These topics must be in the science curriculum (not eg the geography or social subjects areas) partly because they are fundamentally science based but because in the early years it is vital to encourage the children to see this type of study as “science”, a precursor to quantitative analysis and explanation and not as just a descriptive exercise.

*June 2006*

### **Memorandum by the Royal Statistical Society**

1. The Royal Statistical Society is pleased to present evidence to this inquiry.
2. The Society’s evidence focuses on the importance of statistics in the curriculum, both in its own right and as a vital support for scientific and other disciplines, and on steps to be taken to enable pupils to acquire a deep understanding of the statistical principles that underpin so much scientific and technological endeavour. This leads inexorably to the need for good professional development of teachers, both initial and continuing. The Society’s evidence in this area will no doubt resonate with that of many other organisations.
3. The practice of statistics is indispensable within a large number of activities throughout the modern world. Statistical reasoning and modelling are core features in much of science and engineering, and also in the social sciences, humanities, medicine and many other disciplines. More generally, even a cursory study of public debate reveals the pervasiveness of statistical discourse. A basic understanding of statistical ideas is fundamental to an understanding of modern society.
4. Such an understanding might be termed “statistical literacy”. It includes the ability to appreciate how quantitative data are generated, and how such data can be summarised, modelled and interpreted in ways that allow substantively useful conclusions to be drawn about the functioning of the world from which they are derived. It also includes an understanding of uncertainty and how the measurement of uncertainty can be put to constructive uses. This arises, for example, in decision making, in handling risk, and in the formulation and understanding of evidence-based policy. It also involves the ability to critically evaluate the use of statistical data by others, in the media and elsewhere.
5. More specifically within the sciences, statistical understanding is needed to grasp the inherent presence of random variation in all experimentation; to measure, model and allow for that “noise” in meaningful ways; to assist in designing good experiments in the first place, so as to minimise ambiguity of outcomes; and as the basis for a great deal of scientific modelling, sometimes comparatively elementary but sometimes highly advanced.
6. As an area of applied mathematics, statistics brings a vast range of genuine real-life problems into the mathematics curriculum. This can engage students’ interests and bring mathematics to life. Further, the mathematical base of the subject of statistics draws on the use of core mathematical skills such as arithmetic computation, graphical display and interpretation, algebraic manipulation, functions and, at a more advanced level, calculus. It is therefore an appropriate vehicle for learning as well as applying mathematical skills.
7. For these reasons, the Society argues that statistics should be part of the core 11–19 curriculum to which everyone has some exposure. (Indeed, this also extends to the Primary curriculum in terms of activities such as simple counting and arranging, though it may be less likely that the word “statistics” itself would be used.) At least for the foreseeable future, this can only be achieved in a coherent way by retaining statistics as an inherent component of the core mathematics curriculum. This does not imply that applications are unimportant. On the contrary: the process of learning statistics is iterative, moving continually between theory and applications, between mathematical modelling and data analysis. The use of applications from a wide range of disciplines, in the sciences and elsewhere, is vital to ensuring good learning experiences. But the subject is grounded in mathematics, and that, for the time being, is its proper home.
8. This has major implications for teachers of mathematics and of other disciplines.
9. The Society assumes that other respondents will provide quantitative evidence of the shortage of mathematics teachers and the extent to which mathematics is being taught by persons who are not very highly qualified in the subject. The Society supposes that a similar situation may obtain in some science subjects. This is not in any way to decry the abilities of these persons as teachers; they may well be highly effective as such, in a general way. But lack of reasonably high-level subject-specific knowledge is a heavy constraint on ability

to see the development of the subject, put results in an overall context, see where the next steps may be, and impart a general sense of security in the subject to the learners.

10. This problem is particularly acute in respect of teachers of statistics. For the most part, teachers of statistics are teachers of mathematics, based (rightly) in a Mathematics Department, who teach statistics as part of the overall mathematics curriculum. That is fine in itself, but the problem is that very often these teachers have themselves had only a very little formal instruction in statistics, if indeed any at all. This is no criticism of the teachers, or necessarily of the system under which they were trained. They may, for example, have taken a university mathematics degree course in which there was little or no statistics—such courses were common in the past and there are still several today. Thus, even if a mathematics teacher is well qualified in mathematics—and, as pointed out in paragraph 9, that is by no means necessarily the case—this does not imply that the teacher is well qualified in statistics.

11. Even worse in some cases is the situation where some statistics is taught by teachers from other disciplines, in the sciences or elsewhere. Again, no criticism is intended or implied regarding their skills as science (or whatever) teachers. There is, of course, the advantage that they will be close to the areas of application of statistics within their disciplines. But, inevitably, they will not have any overview of the breadth and depth of statistical methodology and its generality and ubiquity of application across wide areas of the curriculum. On the contrary, they will typically find themselves needing to use a limited number of statistical methods within their disciplines, and hence merely teach the use of those methods in an isolated way. Learners then find themselves with poor experiences, facing isolated techniques here and there and some techniques not at all, and with pointless repetition in different disciplines. At best, statistics is then seen by the learners as a marginally relevant technique in some areas of their studies, not as a pervasive and all-important life skill.

12. It is evident that professional development is a vital component of any solution to these difficulties, to ensure proper training of teachers in the relevant statistical knowledge and pedagogy. This applies in respect of both initial teacher training (ITT) and continuing professional development (CPD).

13. The long-term approach is through ITT, and the most important task is to incorporate within it appropriate resources for training of new teachers in statistics. Unfortunately the resources currently devoted to statistics, for example within PGCE courses, are commonly meagre, and courses are substantially full of material already. So the task seems formidable.

14. It appears that something in the nature of a cultural shift is necessary, so that statistics is not seen only as a fairly small discipline in its own right but, instead, as an indispensable key support for many other disciplines. On this basis, replacing parts of other topics or activities by appropriate work in statistics should be viewed as enhancing the other disciplines, not as being to their detriment.

15. The importance of statistics across the curriculum means that, in respect of statistics, some coordination of ITT is needed across subject disciplines. This raises yet further difficulties.

16. The Society does not suppose that the necessary changes to ITT will bring great rewards in the short term, but that is no reason for not proceeding with them. A long term perspective is needed. A useful way forward would be for a small number of well-resourced pilot schemes to be funded, and properly evaluated, for a period of say three to five years in institutions where there is appropriate expertise.

17. Similar arguments can be made in respect of CPD for teachers. Here there is some hope of rewards in the fairly short term, through in-service programmes having the aim of re-skilling existing teachers. Such programmes need to be widely available for existing teachers of mathematics, but there is also a need for programmes—likely to be of a somewhat different nature—aimed at teachers of other disciplines, in the sciences and elsewhere. There may again be ample scope for well-resourced and properly conducted pilots.

18. It is through such programmes that the enthusiasm of teachers is renewed and refreshed. One aspect of this is that teacher retention rates might be improved. Another is of course that learning experiences are enhanced. This should apply throughout the sciences as a consequence of better appreciation of the power of statistics in enhancing scientific method and enquiry.

19. There is, perhaps, reason for some optimism, though these are opportunities that must be grasped positively rather than allowed to lie fallow. In an overall sense, the UK, and especially England, is arguably in the forefront in the general area of statistical education: the Royal Statistical Society attaches great importance to it, and the Royal Statistical Society Centre for Statistical Education is a major source of material including being the base for the international journal *Teaching Statistics* that is focused on teaching at schools and colleges. There exists a wealth of resources and expertise that can be utilised in training programmes such as are outlined above, and indeed by teachers in direct day-to-day teaching.

20. More specifically, the newly created National Centre for Excellence in the Teaching of Mathematics gives a new dynamic and central focus to the whole idea of CPD for teachers. It is earnestly to be hoped that the enthusiasm of the Centre, and the evident goodwill for it throughout the mathematics community, is brought to fruition by accomplishing a step-change improvement. The Centre needs to include CPD for teachers in statistical knowledge and pedagogy as part of its ambit, reaching out also in this regard to teachers of other scientific and non-scientific disciplines. By doing this, there is a reasonable hope that this aspect of teaching in our schools can be enhanced.

21. The following web links are provided for the assistance of members of the inquiry team:

The Royal Statistical Society	<a href="http://www.rss.org.uk">http://www.rss.org.uk</a>
The Royal Statistical Society Centre for Statistical Education	<a href="http://www.rsscse.org.uk">http://www.rsscse.org.uk</a>
Teaching Statistics	<a href="http://www.rsscse.org.uk/ts">http://www.rsscse.org.uk/ts</a>
National Centre for Excellence in the Teaching of Mathematics	<a href="http://www.ncetm.org.uk">http://www.ncetm.org.uk</a>

22. This document is presented to the inquiry with the formal approval of the Royal Statistical Society through its Theme Director for Education and Chair of the Education Strategy Group, Susan Starkings.

*June 2006*

### **Memorandum by the Salters-Nuffield Advanced Biology Centre**

#### **1. THE IMPACT OF EXISTING SCHEMES DESIGNED TO HELP GENERATE ENTHUSIASM IN YOUNG PEOPLE FOR SCIENCE SUBJECTS**

To a certain extent, advanced level biology in England and Wales seemed during the 1990s to be in a healthier state than either advanced level chemistry or physics. The number of candidates grew fairly steadily throughout the 1990s and there appeared, though the data were anecdotal, to be fewer complaints in the UK from those running university biology courses about the knowledge of students coming to read undergraduate degrees in the subject compared to those running university chemistry, mathematics and physics courses.

There were, nevertheless, and still are, worrying concerns about advanced level biology, for there has been mounting (though, again, mostly anecdotal) evidence that much teaching in the subject entails little student involvement, lacks variety and is dull. Perhaps most importantly, we are now in the century that is likely to be dominated by biology and yet there has, until the project reported here, been no major curriculum initiative in the subject in England and Wales since Nuffield Biology was launched over thirty years ago.

As a result, the advanced level biology specifications introduced in England and Wales in September 2000 (a time when all advanced level specifications had to be revised) failed to reflect many of the tremendous advances presently being made in biology in all its diverse fields—molecular biology, cell biology, medical physiology, agriculture, genetics, biotechnology, conservation, behaviour, the brain and evolution. Furthermore, the resulting advanced level biology textbooks and other resources simply reflected the current specifications, presenting a somewhat narrow impression of what it is to be a biologist, whether industrial or academic, and making disappointingly little use of recent developments in Information and Communications Technology (ICT) for teaching and learning.

The Salters-Nuffield Advanced Biology course (SNAB) is a new biology A level designed in response to these concerns. It is intended to engage and motivate students of all abilities and encourage active, student-centred learning. It teaches biological content through topical real life contexts such as coronary vascular disease, conservation biology in zoos and forensic biology. ICT and a wide variety of student-centred learning activities are integrated across all aspects of the course to develop students as active, autonomous learners. Social and ethical issues, requiring students to critically evaluate different viewpoints and come to a reasoned view of their own, are integrated into the contexts. There is a strong emphasis on practical work as a valuable formative experience to develop students' scientific skills and understanding of the processes of science.

Development began in 2000 with wide ranging consultation of expert biologists, teachers, lecturers, educators and students to determine the content and form of the course. Once the course structure and contexts had been agreed, teams of writers—mostly teachers and lecturers—started preparation of pilot course materials. These included a textbook for each unit supported by extensive online resources (both downloadable paper-based activity sheets and interactive tutorials, animations, and tests). These draft course materials were edited by the central SNAB team and then reviewed by biology academics. The pilot specification was developed in parallel with this writing, in partnership with Edexcel, and was approved by the Qualifications and Curriculum Authority (QCA) in June 2002.



Fifty two centres, with approximately 1,500 AS students and 1,000 A2 students, piloted the course each year. The pilot AS began in September 2002, with the pilot A2 starting the following year. Feedback from pilot centres, combined with an independent evaluation conducted by Dr Jenny Lewis at the University of Leeds, enabled a full review of the pilot specification and pilot materials to be undertaken to improve the specification and course materials.

The feedback confirmed that it is possible to teach biological content through contexts to motivate students and that a more active, student-centred approach to learning can be effective. There was high praise for the quality and range of resources and materials, particularly the ICT-based interactive animations. Teachers were mostly delighted with the up-to-date contexts, which they found refreshing and stimulating, and the diversity of supporting activities. Student feedback indicated that they appreciated the context-led approach commenting that it made learning of biological content more relevant:

“It was good having a story running through the topic—could relate to it”

“Relating the cell cycle to cancer really made the ‘concept’ come alive”

The implementation of this course requires both teachers and students to make some re-adjustments to their usual practices. The evaluation highlighted difficulties experienced by teachers and prompted the production of supplementary support materials for teachers such as additional guidance in the teaching notes, the inclusion of concept maps indicating where concepts are introduced and how they build up across topics within the teaching schemes and the production of web-based staff development units.

Teachers were appreciative and enthusiastic about the potential of the ICT resources, particularly in supporting student learning. For some teachers integrating ICT into class teaching was challenging, and strategies for managing the use ICT within the classroom had to be developed. Similar challenges were experienced when teaching about social and ethical issues and when trying to promote active learning. Additional support in these areas has been provided through web-based, staff development units.

Despite the resistance of some students to being asked to think more than usual, the teachers felt that students were generally more interested and motivated by SNAB, even when the work was difficult. Teacher feedback comments have been very positive:

“The content is presented in novel and exciting ways, and the students are certainly enjoying this more than the previous course. The themes make links between biological principles. Topics are related to real life and so are more immediate and relevant. This has been a breath of fresh air as far as AS/A2 Biology is concerned.”

“The students love the story-lines and how it makes biology relevant to them. The whole package is so motivating for tutors and students.”

“It’s great, very refreshing, definitely a winner with the students.”

“Students say they find the course easier because it is more interesting.”

“I’m having to rethink the way I teach, allowing students to think for themselves.”

“We’ve had students come in saying ‘Sorry sir you asked us to read such and such a bit but it was so interesting we just carried on’ . . .”

“Thank you for making this [top school for A level biology in the good schools guide] possible with a demanding course that is also interesting and accessible.”

An Ofsted inspection of one of our centres praised SNAB saying in its official report:

“A major factor in this excellent teaching is the new course which the school has recently adopted. Superb activities and excellent use of information and communication technology lead to progress of exceptional quality. All students achieve very well.”

Many pilot centres have reported improved retention with increased numbers taking the AS and A2 courses. For example, Deacon’s School, Peterborough had 14 AS students last year, 30 this year, and have 46 signed up for next year. King Egberts School Sheffield have seen AS biology numbers rise from 25 to over 80 since the start of the pilot.

The revised AS/A2 specification was approved by QCA in November 2004 for teaching nationally from September 2005. A single, full colour, textbook to support this new AS specification was published in April 2005 and a similar A2 textbook was published in April 2006. The new AS website, complete with additional interactive materials within a managed learning environment, went live in May 2005 with the A2 materials available from May 2006. Over 140 centres started teaching the course in September 2005 with more registered to start in September 2006. More information about this course can be found at [www.advancedbiology.org](http://www.advancedbiology.org).

## 2. THE ROLE OF PRACTICAL WORK IN TEACHING SCIENCE

In the past there has been concern that advanced level biology teaching too often had too little student involvement and that practical work was concentrated on only a small number of experiments used for coursework assessment. The new Salters-Nuffield Advanced Biology course has developed a novel approach to coursework, developing a more formative role for practical work within the course. Practical work is integrated throughout the course and students collect a portfolio of write-ups. The aim is not to produce a perfect write-up as might be required in more traditional assessment systems; rather, each practical is used to highlight experimental and investigative skills.

Half the marks for coursework are awarded on a Practical Work Review. This assesses each student's knowledge of experimental and investigative skills developed during the course. In order to complete the paper for the Practical Work Review students need to refer to their portfolio of completed practical write-ups. The other half of the AS coursework marks are awarded for a report of a visit the student has made or of an issue they have researched. For example, students might go to a hospital, garden centre, biological laboratory or supermarket and then produce a report of particular aspect of the biology they saw in action. Alternatively, students can produce a report on the biology that is related to almost any biological issue.

At A2, each student submits a written report of up to 3,000 words on an experimental investigation they have devised and carried out. This takes the equivalent of two weeks of normal lesson and homework time—of course, this might be spread over much longer than two weeks. These investigations draw on the skills developed during the AS. At A2, students are assessed on their ability to plan and carry out experimental procedures, to interpret their experimental results and to report on their work. The report must include the presentation and analysis of numerical data obtained by the student. It needs to be word processed and submitted electronically.

This approach at AS and A2 encourages centres to complete a range of different practical activities and ensures that all practical work is of value within the course. The method provides good discrimination between candidates for assessment purposes. The completion of individual investigations can be logistically challenging for centres with large numbers but students do appreciate the opportunity to complete an individual investigation.

Overall, Salters-Nuffield Advanced Biology is helpful to reinvigorate advanced level biology teaching. We are determined to ensure that the students who take it find the course to be challenging but immensely satisfying. Biological sciences is still in a healthy state in the UK and we want to play our part in ensuring this continues to be the case.

### **Memorandum by the Science Museum**

#### INTRODUCTION

The Science Museum is part of the National Museum of Science and Industry (NMSI) group of national museums. Others in the group include the National Museum of Photography, Film and Television in Bradford, the National Railway Museum in York and its sister museum, Locomotion: The National Railway Museum in Shildon. All museums in the group operate very successful learning and outreach teams which engage schoolchildren of all ages in science-related educational activity. The Science Museum especially focuses on physics, biology, chemistry and mathematics, and has a world class reputation for science communication and interpretation. The following evidence therefore relates, in particular (though not exclusively), to this museum.

#### EVIDENCE

A more holistic approach to teaching STEM subjects is needed. Formal education alone cannot solve problems in the UK's science learning. In order to tackle the problems of science teaching and the take-up of science subjects, a co-ordinated and complimentary approach between informal and formal learning is required.

Reversing the current decline in practical science and field trips can inspire more students to consider science.

The Science Museum is in a unique position to assist the formal learning sector with its existing huge resources of knowledge and expertise, especially its expertise in using hands-on learning techniques to convey science content. (Please see evaluation of its Energy Gallery and Outreach project below for further evidence.) It has successfully developed innovative teaching methods including interactive, hands-on programming, live events,

the use of real objects, interactive multi-media and dialogue/debate formats on hot issues in contemporary science. These can be transferred/conveyed to teachers and used to reinvigorate the teaching of STEM subjects.

Rigorous training and evaluation mean all NMSI's educational programmes and exhibits are of high quality.

The Science Museum runs a number of very successful school and community outreach projects—eg Creative Canals and Science Night sleepovers, and has gained a high level of expertise in delivering hands-on science programming to hard-to-reach audiences.

The Science Museum and its sister museums within the NMSI group would welcome the opportunity to do more to support the formal learning sector, specifically through sharing and adapting its informal learning expertise for use in the formal classroom. Our experience in using hands-on interactives, our comfort with dialogue and debate, and our success in reaching hard to reach audiences can be a powerful asset to the formal sector. We can provide this assistance at our various museum sites, on-line through electronic resources and out in schools and communities through our outreach programmes.

### **Further Evidence: Science Museum Energy Gallery and Website**

Summary of evaluation conducted by Science Museum Audience Research Unit:

#### **THE ENERGY GALLERY AND ENERGY OUTREACH PROJECT**

- There is significant evidence for learning taking place in the gallery. This included acquisition of new knowledge, reinforcement of existing knowledge, inspiration and motivation, personal learning and developing thinking skills.
- Following a visit to the gallery the overwhelming majority of schoolchildren broaden and deepen their knowledge of concepts related to energy.
- All teachers emphasise the value of the Energy Gallery as both a teaching and learning resource. They felt it successfully engaged and informed their pupils about the subject.

#### **ENERGY INFORMATION ZONES\* (EIZs) AND ENERGY WEBSITE**

- The overwhelming majority of all users describe the EIZs and website as “fun”, “interesting” and “informative”. This is because of the interactivity, their relevance to schoolwork and the amount of information presented.
- All teachers perceive the website to be a highly relevant learning resource for Key Stages 2 and 3, both in addition to a gallery visit, which they feel allows them to extend their children's on gallery experience into the classroom, and as a standalone resource.
- All teachers noted the importance of the Teacher's resource section of the website. They felt that it provided them with information and inspiration on how to engage their children with this difficult subject to teach. They also appreciated the clear National Curriculum links.

\* The Energy Information Zones are found on gallery. There are eight computers in total where visitors can access more information about energy and play energy-related games.

*June 2006*

### **Memorandum by the Science, Engineering, Technology and Mathematics Network (SETNET)**

1. SETNET notes that the focus of this inquiry is the role that teachers and teaching methods can play in reversing the decline in the number of A-level entries in the sciences. SETNET's view is that a significant influence on this decline is an insufficiently wide understanding of the breadth and excitement of the careers that can be pursued with science, technology, engineering and mathematics (STEM) qualifications. We consider that this stems from:

- inadequate and often stereotypical careers advice;
- lack of a uniform approach in connecting schools to local businesses who employ people with STEM skills and qualifications; and
- insufficient take-up by schools, especially in the state-funded (non-grammar) sector, of the STEM curriculum enrichment activities that are offered by a variety of well-qualified organisations, often via the local SETPOINT.

2. We fully accept that the most important influence in engaging young people in STEM education will be the quality of the teaching but equally, as young people today have greater focus on their potential earning power than perhaps they have done in the past, they may well make choices to avoid the “hard” science A-levels if they cannot see rewarding careers at the end of their formal education experience.

3. SETNET welcomed the publication by Treasury, DTI, DfES and DoH in March 2006 of the “Next Steps” to the 2004–14 Science and Innovation Investment Framework but noted that the consultation thereon was limited to areas outside those covered by Chapter 6 “Supply of Scientists”. Notwithstanding this, SETNET submitted a response which highlighted the very strong value of complementing formal science teaching with giving young people a “real world” sense of how the application of STEM subjects can lead to a wide variety of employment opportunities. Having a genuine and well-informed focus on their future career path acts as a stimulus to young people in achieving better qualifications. We are reproducing here some of the points we made in that response which we believe can help to provide young people with the career visions which can stimulate their interest and uptake of science A levels. However, we felt that the lack of any mention in “Next Steps” of how the provision of careers information is to be improved and made into a really effective tool to help increase the interest of young people in studying science subjects, was a significant gap. We are keen that this is not overlooked or sidelined.

#### THE IMPACT OF EXISTING SCHEMES DESIGNED TO HELP GENERATE ENTHUSIASM IN YOUNG PEOPLE FOR SCIENCE SUBJECTS

##### *Regional STEM Support Centres*

4. As DfES’s own Cross-Cutting Review of science curriculum enrichment activities has shown, schools have too often faced a confusing plethora of choices, not all of which are properly linked to the curriculum and not all of which have undergone effective quality testing. This has led to many schools simply not taking advantage of any offerings. SETNET has therefore been pleased to be able to play a leading role in the establishment of the Regional STEM Support Centres which are developing much more strategic and cohesive STEM educational approaches in the English Regions. Piloted in the South East, Yorkshire and the Humber and London areas, early feedback in each of these Regions is highly positive with teachers, Local Authority Advisors and Inspectors, industrial contacts, STEM partners and others immediately supporting the development and clearly identifying with the need for increased cooperation, coherence and clarity. They see the STEM Support Centre as a major step forward in meeting that need.

##### *Science and Engineering Ambassadors*

5. SETNET’s and the SETPOINTS’ links to business and Higher Education allow us to offer appropriately trained Science and Engineering Ambassador volunteers (SEAs) to schools who can act as role models, provide exciting and novel demonstration or project ideas to teachers, and offer assistance with and access to valuable curriculum enrichment activities. The need for such assistance is more relevant than ever as the new Science GCSE Curriculum brings a much stronger focus on real life applications of science and the issues surrounding scientific debate.

Similarly, by providing this unique bridge between businesses and schools, SETNET and the SETPOINTS help employers to gain a better understanding of the skills and attainment of young people, and the way in which they can assist teachers and schools. In addition, employers and individual Ambassadors tell us that they themselves gain from involvement with students and teachers—developing their confidence, presentational and managerial skills as well as, in some cases, igniting interest in teaching as a career option.

#### THE ROLE OF THE PRACTICAL IN TEACHING SCIENCE

##### *Teacher CPD*

7. SETNET and SETPOINTS are committed to supporting those organisations whose key role is teacher CPD in any way possible. Significant work is now taking place to build sustainable partnerships between SETNET, SETPOINTS, the Science Learning Centres and other CPD providers (such as ASE, NAIGS and others) to provide end-to-end experiences where teacher CPD, introduction to enhancement activities and further classroom support can be provided to schools by these organisations working together. Through the new Regional STEM Support Centres SETNET will be working to positively encourage such collaboration

as well as signposting appropriate opportunities to teachers and schools. We will also be encouraging SETPOINTS and others to work with the Science Learning Centres to develop courses that have business support and contexts which are attractive and relevant for teachers.

#### AFTER SCHOOL SCIENCE CLUBS

SETNET strongly supports the development of high-quality clubs for KS3 pupils and, in collaboration with a very experienced set of partners, will be providing DfES with an outline of how to take this pilot forward.

*June 2006*

### **Memorandum by the Society for General Microbiology (SGM)**

#### INTRODUCTION

The Society for General Microbiology, founded in 1945, is an independent professional scientific body dedicated to promoting the “art and science” of microbiology. It has now established itself as one of the two major societies in the world in its field, with some 5,500 members in the UK and abroad.

The Society regards microbiology education as very important, not only because it is a subject within the National Curriculum and post-16 specifications, but because micro-organisms affect everyday life, particularly with respect to infectious diseases and their control. For example, a basic understanding of microbiology enables informed decisions to be made on issues such as the vaccination of children against particular diseases. For these reasons the Society employs a full-time member of staff to support its educational activities, which include compiling and distributing resources to support the curriculum at all key stages and post-16, running training courses in basic practical microbiology for secondary school teachers, technicians and PGCE students and occasional workshops and summer schools for teachers, offering a helpline for teachers and school pupils and hosting a website ([www.microbiologyonline.org.uk](http://www.microbiologyonline.org.uk)). The Society is called upon to give advice by bodies such as the Qualifications Curriculum Authority and the examining bodies and has contributed content to GCSE courses. SGM also has around 400 school corporate members. The Society therefore has a good knowledge of school science education and interacts closely with teachers and technicians.

#### GENERAL COMMENTS

The Society represents a single but important discipline of microbiology within the life sciences and as such is not qualified to comment on many of the issues raised by this consultation. The specific comments made below are based on experience. They also show the valuable role that can be played by a small learned society in fostering science education.

#### SPECIFIC COMMENTS

##### *Teaching science*

##### The Adequacy of Professional Support for Science Teachers

Teachers' background knowledge of microbiology varies considerably from none to a degree in the subject, yet they are required to teach it and most people benefit from specialist training. This is available from SGM in the forms of free or low cost resources tailored to the curriculum and courses. Demand is high and tens of thousands of copies of our resources have been distributed over the years. Teachers are also eager to attend courses and have funding for the fees, but they are often unable to get out of school unless supply cover is provided. The SGM therefore makes a financial contribution to the latter. As a result hundreds of teachers have received training in basic practical microbiology over the past four years. Funding for supply cover is an important but often overlooked factor in ensuring that teachers benefit from the in-service training opportunities available.

## The Role of the Practical in Teaching Science

Practicals are very important in engendering enthusiasm for science in school students, but difficulties arise due to large classes, timetabling issues, short lesson times and unwarranted health and safety considerations. Clearer guidance should be made available on safety issues as it is SGM experience that teachers are often misinformed about what is allowed and do not know where to find authoritative advice. As well as providing information of this type, SGM has devised interesting practical activities that can be carried out successfully in standard lesson periods. These are very popular with students. Adapting scientific investigations to fit in with timetabling and other constraints is easily achieved and should be encouraged.

## SCHOOLS

*Variations between schools in the teaching of science, including specialist schools, academies and Community Technology Colleges; procedures for exchange of best practice*

There are sometimes differences in science teaching in the independent and state sectors that are basically due to a lack of funding in the latter. For example, thanks to higher staffing levels, single sciences at GCSE are more readily available in independent schools, with students benefiting from specialist teachers and more in-depth coverage of biology, chemistry and physics. Private schools also tend to run more after-school science clubs, another factor in raising student enthusiasm for science; such clubs also enable topics to be covered that are outside the curriculum.

The Society has found when organising residential microbiology summer schools for post-16 biology teachers that the majority of attendees are from independent schools, mainly because supply cover is not a problem and they are allowed to be absent from school in order to receive training. Their students benefit by having teachers with up-to-date knowledge and new ideas for curriculum-driven activities and the teachers also have a valuable opportunity to share best practice. It is unfortunate that teachers from different schools seem rarely to meet.

Addressing these funding issues would ensure that the profile of science in all schools is maintained at the same high level.

*Links between schools, universities and industry, to facilitate science teaching*

There are many schemes in operation, such as Researchers in Residence and those run by SETPOINTS, which are effective in taking scientists into schools. If anything, the multiplicity of schemes is confusing and some streamlining would be helpful, to ensure that schools are aware of the opportunities available and scientists can easily find out how to get involved. The Society offers advice on suitable activities and provides resources to its members in universities, research institutes etc. visiting their local schools and has a grants scheme to help larger initiatives, such as groups of children visiting a university lab to carry out microbiological activities. Feedback has proved that these interactions between “real” scientists and school students are invaluable in raising enthusiasm for science and should be encouraged. They also benefit teachers in raising awareness of different aspects of science and providing networking opportunities. University staff find out what their potential future students are learning in school and also have the opportunity to promote their undergraduate courses.

## SOURCES

This evidence has been prepared on behalf of SGM by Janet Hurst, Deputy Executive Secretary, 19 June 2006 (Tel: 0118 988 1809, email: j.hurst@sgm.ac.uk).

## ABOUT THE SGM

Society membership is largely from universities, research institutions, health and veterinary services, government bodies and industry. The Society has a strong international following, with 25% of membership coming from outside the UK from some 60 countries.

The Society is a “broad church”; its members are active in a wide range of aspects of microbiology, including medical and veterinary fields, environmental, agricultural and plant microbiology, food, water and industrial microbiology. Many members have specialised expertise in fields allied to microbiology, including biochemistry, molecular biology and genetics. The Society’s membership includes distinguished, internationally-recognised experts in almost all fields of microbiology.

Among its activities the Society publishes four high quality, widely-read research journals (*Microbiology*, *Journal of Medical Microbiology*, *Journal of General Virology* and *International Journal of Systematic and Evolutionary Microbiology*). It also publishes a highly respected quarterly magazine, *Microbiology Today*, of considerable general educational value. Each year the Society holds two major scientific meetings attended by up to 1,500 microbiologists and covering a wide range of aspects of microbiology and virology research.

The governing Council of the SGM has a strong commitment to improving awareness of the critically important role of microbiology in many aspects of human health, wealth and welfare. It has in this connection recently initiated a "Microbiology Awareness Campaign" aimed at providing information to the government, decision makers, education authorities, media and the public of the major contribution of microbiology to society.

An issue of major concern to the Society is the national shortage of experienced microbiologists, particularly in the field of clinical microbiology and in industry. To attempt to improve this situation long-term, the Society runs an active educational programme in schools, universities and colleges and promotes careers in microbiology to all sectors.

June 2006

### Memorandum by Stoke-on-Trent Museums Service

1. Although the lines of enquiry for the Committee refers to links between schools, universities and industry to facilitate science teaching, we submit that sites of out of school learning, particularly those provided by museums, have an important contribution to make in supporting science teachers in schools and in the generation of enthusiasm in young people for science subjects.

- As professional museum educators, we are aware of the importance of working with a variety of learning styles and the need to exploit the hands-on and interactive approach that a museum can offer. From this we believe that a museum can provide a valuable and stimulating day away from the classroom for all learners.
- A majority of current school visitors to the museums in Stoke-on-Trent are at KS1 and 2 but we are aware of the work that shows that stimulation of an early interest in science is likely to result in a lasting interest in science.
- The breadth of material in our museums fosters a cross curricular approach, putting our science sessions in context in a way that would not be possible in a classroom. Above all, museum learning provides an opportunity to engage first hand with objects that offer a tangible manifestation of particular scientific principles.

2. In Stoke-on-Trent, we are developing a range of additional science workshops for KS3 pupils in collaboration with school teachers. This collaboration is of considerable value to both parties as we each discover ways to use the other's strengths. It also means that we can "test-drive" sessions with the help of teachers and pupils in order to deliver programmes that meet their learning needs and stimulate an interest in science.

3. In addition, in common with other museums, we are working with Initial Teacher Training providers and hope to have an impact on the effectiveness of teacher training in science subjects.

- Museums educators are generally specialists who cover a smaller range of topics and can share their expertise in conveying these with teachers and student teachers.
- Student teachers can often share their enthusiasm for new teaching ideas, ensuring that the museum educators keep abreast of new ideas and methodology and validating their own knowledge.
- Museum educators can share their experience of how to make a day away from the classroom a valuable, cross curricula, learning experience that supports and extends school-based learning.

4. To give an example, Stoke-on-Trent Museums are currently working with Keele University ITT and our Primary Science Advisory group of teachers on the development of an innovative approach to teaching the concepts of heat and the principles of scientific investigation to years six to eight. We have also had preliminary discussions with the Science Learning Centre. Our objective is to place these concepts in a real life situation, both historically and in the present during an exciting hands-on day out of school in our working pottery.

5. We believe that, in addition to specialist science centres, broader based museums services such as Stoke-on-Trent have a valuable role to play in generating enthusiasm for science and in the effectiveness of placing science teaching in context for student teachers.

### Memorandum by the Wellcome Trust

1. The Wellcome Trust welcomes the opportunity to respond to the questions raised by the House of Lords Select Committee on Science and Technology in its inquiry on science teaching in schools. The Trust predominantly funds research in the biomedical sciences. However, in order for the UK to maintain a healthy and competitive biomedical research base, it is imperative both that the strength of biology is maintained and that the chemistry, physics and mathematics disciplines are robust. Increasingly, interdisciplinary approaches are also required to tackle complex questions. Therefore, we welcome the commitment of the Government in the “*Science and Innovation Investment Framework 2004–14: Next Steps*” document to achieve year on year increases in numbers of young people taking A-levels in these subjects.
2. We believe that a key to effective delivery of this target is high quality and inspiring teaching from well-trained teachers. Enhancing the quality and teaching of science subjects relies on improving the recruitment and retention of science teachers, and supporting their continued professional development (CPD).

#### THE ADEQUACY OF PROFESSIONAL SUPPORT FOR SCIENCE TEACHERS

3. The need for CPD in science education reflects the rapid pace of development in contemporary science; a greater awareness of the social and ethical context within which research is conducted; and advances in information and communications technology, which open up new opportunities for learning. The biggest determinant of student engagement in the classroom, at all ages, is teacher quality—therefore the focus must be to ensure science teachers are of the highest quality and are fully engaged with their subject throughout their careers so they can enthuse and inspire pupils.
4. In 2005, the Wellcome Trust commissioned a survey of teachers and managers in state maintained schools in England to determine teachers’ views about CPD. The resulting report, “*Believers, seekers and sceptics: what teachers think about continuing professional development*”, revealed strong support for CPD particularly to update subject knowledge. 73% of secondary science teachers wanted more subject-related training, compared to 60% for other subject teachers. However, half of all secondary school science teachers have had no subject related CPD in the past five years. Only half of secondary heads of science felt that their senior management encouraged CPD.
5. Provision is now in place to deliver high quality CPD for science teachers through the Science Learning Centres, a £51 million partnership between DfES and the Wellcome Trust.<sup>87</sup> Nine Regional Centres, and one National Centre based in York, provide a network for professional development in science teaching, supporting science teachers and technicians to develop new skills and experiment with innovative techniques. In 2005, over 9,000 training days were delivered at the Centres, and the feedback from those who attend has been consistently positive.
6. However, a number of barriers are preventing teachers from benefiting from professional development at the Centres. One of the major obstacles in tackling national strategic imperatives is the devolved budget at the level of the school. At present there is no incentive or imperative for schools to prioritise CPD for science teachers. Early indications from teachers attending courses at the National Science Learning Centre are that they can only attend courses if there is external funding to assist with the cost of supply cover and course fees. Teachers also cite concerns that there is little or no entitlement to subject-specific CPD and difficulty in obtaining permission to attend courses.
7. In 2001, the House of Lords Select Committee on Science and Technology concluded in its report, “*Science in Schools*”, that CPD was particularly important for those who teach science and recommended that “for CPD to be effective, regular time must be formally allocated to subject-specific development.” We argue that there is still not a culture that encourages subject-specific CPD to be viewed as an entitlement. To achieve the vision for the Science Learning Centres, school head teachers and managers need to see the value in encouraging and funding science staff to engage in CPD, and government agencies must provide incentives for subject-related external CPD.
8. As for any other profession, there is particular value in delivering some science CPD in a specialist out-of-school environment. The National Science Learning Centre provides the opportunity for staff to attend courses in state-of-the-art facilities where they can learn from practising scientists and from other teachers, outside their normal working environment. This is especially important for science given the fast-moving nature of the discipline and the need for students to relate what they are learning in the classroom to what is

<sup>87</sup> <http://www.sciencelearningcentres.org.uk/>



being aired in the media. Further, given the lack of specialist science teachers in many schools,<sup>88</sup> the importance of off-site CPD becomes even more relevant. The National Centre runs intensive residential courses, which can help to fill this gap.

9. The Wellcome Trust has provided a 10-year investment in the National Science Learning Centre, with reduced funding from year five. The initial commitment from the Government to the regional centres was for five years, until the end of March 2008. It will be crucial for further commitment to the initiative to be maintained if longer-term sustainability is to be realised. The Science Learning Centres can also play a role supporting Government in delivering the policy commitments outlined in the “*Science and Innovation Investment Framework 2004–14: Next Steps*”, for example by developing and piloting a CPD programme leading to an accredited diploma for existing science teachers without a physics and chemistry specialism.

#### THE EFFECT OF CHANGES IN THE CURRICULUM ON ATTRACTING/RETAINING SCIENCE TEACHERS

10. “*Believers, seekers and sceptics*” found that secondary heads of science have lower levels of morale, and less confidence in their performance and subject knowledge, than other teaching professionals. This will have an impact in the classroom. CPD is seen to be a way to help improve confidence, and will be particularly important with the introduction of the new science curriculum.

11. The success of the new science GCSEs will be heavily dependent on the way they are taught. Teachers must develop new skills and innovative techniques to deliver the new curriculum effectively. Additional training and guidance provided through tailored CPD will be vital to ensure teacher confidence. The Science Learning Centres have already found that courses about the new GCSEs have a much higher take-up because they are seen to be essential for schools.

12. In 2005, the Wellcome Trust published “*Primary Horizons: starting out in science*”, examining teachers’ views and experiences of primary science across the UK. The report highlighted the lack of confidence of primary teachers to deliver the current science curricula effectively, with 50% of respondents stating that their lack of knowledge, expertise, confidence and training was their main concern in teaching science. Most primary teachers are not science specialists and would benefit from greater support to help them develop their science teaching skills and increase their confidence. The report concluded that primary teachers should also be provided with more opportunities for career-long CPD in science.

#### THE IMPACT OF EXISTING SCHEMES DESIGNED TO HELP GENERATE ENTHUSIASM IN YOUNG PEOPLE FOR SCIENCE SUBJECTS

13. The Science Learning Centres have already provided successful CPD for running after school science clubs, and could play a role in establishing the after school science clubs announced in the “*Science and Innovation Investment Framework 2004–14: Next Steps*”.

14. We also look forward to seeing the results of the STEM mapping review, and are encouraged by initial indications that it intends to improve co-ordination of the wide range of science education activities at a local and regional level. The Science Learning Centre Network’s web portal provides an ideal mechanism to co-ordinate science teachers’ access to educational resource material. Consideration should be given to providing funding to maximise the potential of the portal to become the “British Library” of school science resource material, thus ensuring co-ordinated access to the plethora of materials that are produced for science teachers.

#### THE ROLE OF THE PRACTICAL IN TEACHING SCIENCE

15. A number of recent reports have highlighted the importance of teaching laboratory and investigative work, to enable students to develop the practical skills needed for work in universities and industry.<sup>89</sup> In order to improve the quality of practical experimentation, teachers and technicians will need CPD to develop their confidence and skills. The Science Learning Centres provide opportunities for teachers to update their practical skills in a state-of-the-art environment, with access to the latest equipment and techniques.

<sup>88</sup> DfES Research Report RR708 (2006) *Mathematics and Science in Secondary Schools: The Deployment of Teachers and Support Staff to Deliver the Curriculum*.

<sup>89</sup> Biosciences Federation (2005) *Enthusiasing the next generation*. Association of the British Pharmaceutical Industry (ABPI) (2005) *Sustaining the skills pipeline in the pharmaceutical and biopharmaceutical industries*. The National Endowment for Science, Technology and the Arts (NESTA) (2005) *Real Science—Encouraging experimentation and investigation in school science learning*.

16. In 2004, the Wellcome Trust published a report “*Life study: Biology A-level in the 21st century*”, examining views and attitudes towards GCE biology A-Level in schools in England. The research found that there was considerable variation in the amount of practical work undertaken by A-level students but, overall, students were doing less practical work now than in the past and often had weaker practical skills at university level. The report recommended that a broader range of practical investigation should be encouraged in the coursework component of biology A-level. The need to support teachers through professional development to enable them to deliver practical work was also recognised.

17. We would be happy to discuss any of the issues raised in this response in more detail if this would be helpful.

### Memorandum by the Natural History Museum

This is a corporate submission on behalf of the “Real World Science” project, a partnership between the Natural History Museum (NMH), the Manchester Museum (MM), the Oxford University Museum of Natural History (OUMNH) and the Hancock Museum (HM). The evidence given is fully endorsed by the Directors of each Institution.

#### SUMMARY

1. The Real World Science Project has demonstrated the valuable contribution that natural history museums can make to secondary science teaching and learning by developing an innovative and high quality learning programme based on teacher consultation. The programme uses the museums’ collections, galleries, curators, scientists and educators. It has attracted 5,985 secondary science students in its first two years and is targeted to reach 8,750 students in the current project year. Initial results from the programme are extremely encouraging: 22% of students attending AS/A2 Biology days at the Natural History Museum reported that their plans for studying science further had been affected in a positive way. The next phase for the partnership is to build capacity in natural history museums across England to use their resources to support secondary science students and inspire them to study science further.

#### INTRODUCTION AND BACKGROUND

2. The evidence below is submitted on behalf of the partnership of museums forming the Real World Science Project<sup>90</sup>, which is funded by the Department for Culture, Media and Sport, and the Department for Education and Skills through the Strategic Commissioning Education programme. This partnership has been in place since April 2004 and has received £395,000 in Strategic Commissioning funding.

3. The partnership has developed a powerful and engaging learning programme for secondary science students. This age group was prioritised in order to address a significant gap in museum education provision for secondary science. The partners initiated the project in the conviction that high quality learning programmes at natural history museums could raise aspirations and counter the lack of science uptake post-16. A key aim of the partnership is to inspire students to continue their scientific studies to A-level or university, and thus into scientific careers.

4. The programme has attracted 5,985 secondary science students in its first two years (April 2004–March 2006) and is targeted to reach 8,750 students in the current project year (April 2006–March 2007).

5. The key aims of the “Real World Science” project are to:

- inspire secondary science students to continue their scientific study to AS/A2 Level, and further to undergraduate level, through vibrant and compelling museum-based activities, including encounters with world-class practising scientists;
- enable students to understand the impact that science has on their lives and to make informed decisions based on analysis of scientific evidence; and
- increase the number of secondary science students and teachers using natural history museums to support their science teaching and learning.

6. The partnership has recently published the results of a major consultation with science teachers undertaken in 2005.<sup>91</sup> The results of the consultation confirmed the partnership’s conviction that the out-of-classroom learning experience of a structured visit to a natural history museum, including encounters with practising

<sup>90</sup> The partnership comprises the Natural History Museum [NHM], the Manchester Museum [MM], the Oxford University Museum of Natural History [OUMNH] and the Hancock Museum [HM].

<sup>91</sup> Collins, S & Lee, A (2006) How can natural history museums support secondary science teaching and learning? London: Natural History Museum.

scientists and curators, was highly valued by secondary science teachers. The consultation report shows overwhelmingly that natural history museums can have a substantial role to play in supporting science curriculum delivery, particularly in hard to teach areas, and in bringing science and its applications to life. The teachers felt that the museums provide unparalleled resources that are rarely available in school to support the teaching of challenging scientific concepts.

7. The top four themes to emerge from the research were that natural history museums can play a vital role in:
- providing opportunities for students to meet practising scientists who can positively influence attitudes to learning science, career choices and can support teaching the new science curricula;
  - offering fun and engaging workshops, debates and demonstrations with a strong practical element;
  - engendering, through their collections and galleries, a sense of awe and wonder about the natural world; and
  - supporting the course work elements of new GCSE's and AS/A2 exams including Twenty First Century Science, Salters-Nuffield Advanced Biology and Perspectives on Science, all of which have an emphasis on the application of scientific research.

## ATTRACTING SCIENCE TEACHERS

### *The effectiveness of teacher training in science subjects*

8. The partnership supports Initial Teacher Training by providing short placements to PGCE and BED students, highlighting the effectiveness of museum resources in enhancing their teaching throughout their careers. This programme has been developed through strong links with university education departments:

- Natural History Museum (King's College London, Exeter University).
- The Hancock Museum (Newcastle University).
- The Manchester Museum (University of Manchester, Manchester Metropolitan University).
- Oxford University Museum of Natural History (Oxford University, Oxford Brookes University).

9. As institutions that depend on practising scientists, it is core to our missions to support the engagement, initial teacher training and retention of science teachers. Placements provide teacher trainees with a valuable opportunity to understand the role of museum education departments and the scope of the museums' scientists, collections and galleries in supporting the science curriculum and as an inspiration to their future students.

10. The Oxford University Museum of Natural History has demonstrated the effectiveness of this approach through collaboration with the Oxford University Department of Education Studies. The museum has provided PGCE students with the opportunity to develop, with museum education staff, a science enrichment day for 270 year 9 students. Two teacher trainees are currently working with the museum education team to determine how the museum can support the KS4 programme of study and the new aspects of the GCSE course. The PGCE students will engage with University scientists and work on pre and post visit activities in order to prepare students to gain the most from their museum visits.

## TEACHING SCIENCE

### *The adequacy of professional support for science teachers*

11. Science is a wide-ranging subject, and science teachers rarely have access to up-to-date research on subjects outside their personal specialisms. The Real World Science partnership enables teachers to have direct contact with scientists working in natural history museums as well as in universities. The consultation with teachers highlighted the need to provide particular support for teachers in the areas of earth sciences and taxonomy. A report by the Science Learning Centre in London in 2004<sup>92</sup> indicated that Science teachers wanted hands-on Continuing Professional Development (CPD) activities that promoted cutting edge science practical skills.

12. The natural history museums in the "Real World Science" partnership are well placed to support the professional development of teachers in science education through workshops and other activities.

<sup>92</sup> Hall, A, Malek, R, Styliandou, F (2004) Continued Professional Development; a scoping study commissioned by the London Challenge. London: Science Learning Centre.

- The museums' collections and galleries are highly relevant to the secondary science curricula and offer an excellent base for providing teachers with science updates and new ideas for student activities. They are particularly supportive of life and earth science teaching and provide an outstanding demonstration of biodiversity, interdependence and adaptation in the natural world.
- The museums have an invaluable resource in the work of their research and museum scientists. Contemporary science provides a means of developing relevant and engaging case studies that teachers can use, particularly in light of the new curriculum's emphasis on "how science works".

13. Following on from the 2004 report<sup>93</sup> the Natural History Museum established a secondment programme with both the Institute of Education and the Science Learning Centre London in order to enhance its ability to provide professional development opportunities for science teachers. The resultant programme is designed to stretch and reinvigorate science teachers, raising their confidence, particularly in areas that are difficult to teach.

The Museum has a programme of CPD workshops for 2006–07:

- Rocks, volcanoes and earthquakes, the ever changing earth—an earth science workshop for teachers of KS4 science in collaboration with the Earth Science Teacher's Association.
- How science works at the Natural History Museum—this workshop is designed to support the teaching of the "how science works" element of the new KS4 Science specifications, and is run in concert with a micropalaeontology workshop for KS4 students.
- Astronomy: The universe and solar system—in collaboration with the Science Museum.
- Classification, Adaptation and Evolution—how the NHM can support KS4 and Post-16 Biology.
- Plant Science—designed to support the delivery of plant science and ecology components of the post-16 biology curriculum.

14. Teachers visiting the Manchester Museum are able to engage with young research scientists and experience new techniques in science providing case studies about new developments and applications in science.

15. At the Hancock Museum, teachers benefit from being able to draw on the expertise of scientists working on the Geological and Biological collections. Museum scientists have also run CPD courses for teachers on the subject of geology.

*The effect of changes in the curriculum on attracting/retaining science teachers*

16. The new emphasis on "how science works" at KS4 provides an opportunity for natural history museums to support teachers directly and to capture student interest in a curriculum area that is difficult to convey in the classroom. The Real World Science partnership aims, therefore, to provide teachers with the resources and expertise to teach the new syllabus effectively, thus encouraging the retention of teaching staff. New programmes, designed in partnership with practising teachers and syllabus developers, respond to curriculum changes and reflect new initiatives in teaching styles.

17. Teachers at the OUMNH highlighted that in the new Twenty First Century Science GCSE, students are required to examine how certainties in science and scientific ideas change over time. They pointed out that the Museum's association with Darwin, workshops communicating Darwin's impact on Victorian science and society, and its access to modern-day scientists provide a valuable resource to support this area of the curriculum and the requirement for the case studies, which form 20% of the students' coursework.

*The impact of existing schemes designed to help generate enthusiasm in young people for science subjects*

18. The four museums in the "Real World Science" partnership are uniquely placed to act as an inspiration for secondary science students because of their:

- Extensive natural history collections of international significance;
- World-class curators and scientists involved in active research;
- Experienced museum education staff and provision for large numbers of school visits;
- Awe-inspiring exhibitions and galleries, with programmes and displays linked to the National Curriculum.

<sup>93</sup> Hall, A, Malek, R, Styliandou, F (2004) Continued Professional Development; a scoping study commissioned by the London Challenge. London: Science Learning Centre.

19. In response to our consultation with science teachers, the partnership has developed an innovative programme delivered to secondary science students in a museum context. These resources are tightly linked to the curriculum and are presented in ways designed to be inspirational to further study and careers in science. The programme covers Life and Earth science subjects across KS3–AS/A2:

- KS3 The Rock Cycle day (HM)—practical demonstrations linked to gallery displays;
- KS3 Plate Tectonics, Earthquakes and Volcanoes show (NHM)—a fun science show using large props, messy experiments and audience participation;
- KS3 Elements, mixtures, rocks and fossils workshop (OUMNH)—identification of rocks via a giant floor puzzles and looking for fossil evidence in the galleries;
- KS3/4 Forensic science workshop (MM)—students process DNA and use gel electrophoresis to separate it into fragments;
- KS3/4 The Great Debate workshop (OUMNH, NHM, HM)—a recreation of the Great Evolution Debate of 1860. Students examine the selection and interpretation of evidence from the museums' galleries;
- KS4 Evolution day (HM)—Students are challenged to find evidence for evolution in the museum's galleries and take part in a fossil hunt in a mound of shale;
- KS4 Earth Science workshop (MM)—students carry out practicals with scientists from the University of Manchester's School of Earth, Atmospheric and Environment Sciences;
- KS4 How science works workshop (NHM)—a practical activity developed with Museum micropalaeontologists, reflecting their working methods;
- KS4 Science behind the headlines (OUMNH)—scientists describe their work and career path before leading a discussion with students on the portrayal of science in the media;
- AS/A2 Genetics day (MM)—students discover how biology at A-level translates into real research projects and visit the North West Genetic Knowledge Park meeting researchers and genetic counsellors;
- AS/A2 Biology day (NHM)—students go behind-the-scenes meeting scientists and curators to discuss their research and collections. The day supports the visit report element of the new Salters-Nuffield Advanced Biology course;
- AS/A2 Chemistry day (NHM)—talks and practicals with Museum Mineralogists and geochemists. This day supports all A-Level chemistry syllabi and the Salters Advanced Chemistry in particular; and
- AS/A2 Study days on—molecules, cell & systems, genetics and ecology (OUMNH)—practical activities, lectures and interactive tours with scientists from various university science departments.

20. Working through subjects such as forensic science and genetic engineering, Manchester Museum workshops provide opportunities for KS3, 4 and 5 students to experience practical science, to use modern techniques such as gel electrophoresis and to learn from young research scientists about the reality of a career in science. Other sessions provide opportunities for students to engage with advances in research in the biosciences.

21. Programmes running at the Hancock Museum through the partnership continue to generate engagement with the topics covered and enthusiasm for science, demonstrated by numerous positive comments from participants. For example, fossil hunting as evidence to prove evolutionary theory generated excitement as students realised that the fossils they had unearthed had not been exposed to the naked eye for 300 million years!

22. The impact of the Real World Science project has been evaluated annually and in the 2005–06 project year this gathering of evidence was undertaken against the following Learning Outcomes:

- Students feel inspired and enthused to pursue a career in science—22% of students attending the NHM's AS/A2 Biology day reported that their plans for studying science further had been affected in a positive way. Across the partnership, 13% of the students attending the programme responded that they had been inspired to continue studying science. Strong qualitative evidence was gathered indicating that encounters with scientists were influencing students' career decisions.
- Students understand that there are different ways of interpreting evidence and can relate this to historic and contemporary examples of scientific research—44 out of 46 students the Great Debate workshop at OUMNH agreed with the statement "The activities helped me to understand the way scientific ideas are influenced". A student at the Hancock Museum said that the workshop "... allowed a visualisation of what the debate was at the time and it was entertaining". At the

NHM, one student commented that “Everyone was enthusiastic and it made everyone really motivated . . . I wasn’t really sure about evolution, but I am now.”.

- Students gain more knowledge of how scientists work through engaging with examples of real scientific research—feeding back on the AS/A2 Biology day at the NHM, 37% of students were able to write down a practical use for the scientific research they had seen during the day. One of the students attending the Forensic Science workshops at the Manchester Museum said that they “. . . saw what science is used for. I could see the applications of techniques we learnt about in lessons.”.
- Students have an enriched experience of science and feel more positive towards the subject—across the partnership, 40% of students felt that their feelings towards science had changed positively as a result of their museum visit. Students appreciated the value of the museum environment with one student at the Hancock Museum commenting “. . . evolution can be enjoyable not like in lessons”. Many students felt more enthusiastic about science and that their perceptions of scientists had changed; a student at OUMNH said “. . . there were some girls—I always assumed scientists to be men.”.
- Students have a greater appreciation of the diversity of life on earth and how we classify it—students were amazed by the number of species in the world and how rare some of the species are and how many specimens the museums had. One student at the NHM was inspired by “. . . looking at the most rare specimens in the world.” The Taxonomy workshop which forms part of the NHM’s AS/A2 Biology day was enjoyed by 73% of the participants with 19% indicating that it had increased their knowledge and understanding of taxonomy.

#### *The role of the practical in teaching science*

23. The Manchester Museum report that detailed evaluation of their sessions showed that practical workshops increased skills, extended knowledge and demonstrably improved attainment in science subjects among secondary pupils.

24. At the Hancock Museum, practical tasks provide students with the opportunity to try ideas out for themselves and come to their own conclusions. For example, students had the opportunity to work with a wide range of museum specimens from different animal groups to examine the pentadactyl limb. Students could also compare and contrast suture lines on ammonites to come up with ideas about adaptation in the fossil record. Students were challenged to enter into the debate between evolution and creationism and to form their own arguments.

25. At the NHM, scientists and museum educators have developed a laboratory procedure for school workshops that reflects the scientists’ work and challenges students to solve an authentic scientific problem. The Co-Director of the Twenty First Century Science GCSE was consulted to ensure that it supports the “how science works” component. Students responded to the technique’s authenticity and the satisfaction gained in solving the problem, students wrote, “It was really fun and I learnt a scientific procedure”, “I felt so clever” and “We did work that a proper scientist would do so I felt really smart.” In the role of scientists, students had to reach a consensus as a class on the geological age of a clay sample after processing it and identifying the microfossils present.

## SCHOOLS

#### *Links between schools, universities and industry, to facilitate science teaching*

26. The special position of the Manchester Museum as a university museum gives it the opportunity to act as a gateway to higher education for school students enabling them to experience real life science, to meet researchers and to gain skills and knowledge in scientific research. It also gives university students who work with us the opportunity to gain teaching experience, encouraging some to enter teaching and giving all valuable experience in communicating science to non-specialists.

27. Strong links between schools and museums are essential to support, develop and improve science learning. The Hancock Museum is managed by Tyne & Wear Museums on behalf of Newcastle University, so its proximity to science specialists creates huge scope to forge links with science teaching and learning over future years. Museums provide opportunities for both students and teachers to become familiar with historical developments in science in order to understand the position that we are in today. At the same time, the role of the museum in current scientific research means that students and teachers are provided with experiences,

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resources and approaches to learning that support and extend the science curriculum in school and reinforce its relevance to the modern world.

28. Outside of the partnership, the NHM has established links with both University College London (UCL) and Imperial College, organising summer schools for KS3/4 and A-Level students which introduced them to working with primary sources and to study skills that will help with their schoolwork and future undergraduate studies. In July 2006 a summer school entitled “Conservation and Extinction: Past, Present and Future” will take place for 30 year 12 students. They will be given the opportunity to discuss scientific issues with academic input from the Grant Museum of Zoology (UCL) and scientists at the NHM.

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