S&T Committee: Written evidence

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Practical experiments in school science lessons and science field trips: 19 July 2011

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03	Edgar Jenkins, Emeritus Professor of Science Education, University of Leeds
04	Scottish Schools Equipment Research Centre
05 05a	British Science Association Supplementary
06	Earth Science Teachers' Association
07 07a	Field Studies Council Supplementary
08	School Travel Forum
09	Myscience
10 10a	Council for Learning Outside the Classroom Supplementary
11	The Perse School
12	City and Islington College
13	Institution of Chemical Engineers
14	RSPB
15	The British Psychological Society
16	Association of the British Pharmaceutical Industry
17	Dr Philip Wheeler and Dr Graham Scott, University of Hull
18	OCR (Oxford, Cambridge and RSA Examinations)
19	The Linnean Society of London
20	Ofqual (Office of Qualifications and Examinations Regulation)
21	Research Councils UK

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22 22a	The Royal Institution of Great Britain Supplementary
23	The Gatsby Charitable Foundation
24	Assessment and Qualifications Alliance (AQA)
25	British Ecological Society
26 26a	CLEAPSS Supplementary
27	National Union of Teachers
28	The Geological Society of London
29	Natural History Museum
30	EngineeringUK
31	The Wellcome Trust
32	Ruth Amos and Professor Michael Reiss (Institute of Education, University of London) and Dr Ian Abrahams, Professor Robin Millar and Mary Whitehouse (University of York)
33	SCORE
34	Teacher Scientist Network
35	(duplication)
36	Royal Geographical Society (with IBG)
37	Campaign for Science and Engineering (CaSE)
38	The Science Council
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40	NASUWT
41	The UK Association for Science and Discovery Centres
42	Health and Safety Executive (HSE)
43	Association of British Insurers
44	Ofsted
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Written evidence submitted by the Department for Education (Sch Sci 00)

Introduction

Science is a critically important subject for this country. The Schools White Paper: *The Importance of Teaching* acknowledged the importance of a "strong national base of scientific skills" providing a clear commitment to provide additional support to improve take up and achievement in the sciences in schools and colleges.

Practical science delivered with flair and knowledge can help pupils understand scientific concepts and ignite their interest in physics, chemistry and biology. Practical science is also an important part of scientific knowledge and teaches pupils about the empirical basis of scientific enquiry.

The key to making sure that good quality practical science contributes fully to effective science teaching is having high calibre science teachers and technicians in place. It is also important that existing teachers have access to good quality professional development opportunities and that they teach to a curriculum that provides them with the freedom they need to teach science in a way that best suits the needs and aspiration of their pupils.

International comparisons

PISA 2009 showed that the UK performance in science continues to fall down the international rankings. England is now only marginally above the OECD average and so clearly there is much to be done to improve the general standard of science education if we are going to compete with the best in the world.

PISA 2006 (the most recent survey where science was the main focus) provides mixed results on the prevalence of practical science and field trips in England. We compared well internationally on the amount of time students spent doing practical experiments. This was supported by analysis[1] undertaken by SCORE[2] which found that in the UK more practical work takes place in science lessons than in most other countries. However, PISA 2006 data also showed that students in England tended to take part in slightly fewer excursions or field trips when compared to other countries.

[1] Practical work in science: a report and proposal for a strategic framework, December 2008
[2] Science Community Representing Education. Members comprise the Institute of Physics, Royal Society of Chemistry, Society of Biology, Association for Science Education, Royal Society and the Science Council.

Data from the PISA 2006 Student Questionnaire

When learning science topics at school, how often do the following activities occur?							
Students spend time in the laboratory doing practical experiments							
	England	Wales	Northern Ireland	Finland	New Zealand	Japan	OECD Average
In all lessons	-	3%	2%	2%	3%	3%	4%
In most lessons	24%	17%	16%	20%	18%	7%	16%
In some lessons	62%	67%	66%	52%	57%	44%	43%
Never or hardly ever	11%	13%	16%	25%	12%	45%	30%

The way forward

The latest Ofsted report on science education[3] found that more practical science lessons and scientific enquiry were key factors in schools which showed clear improvements in promoting students' engagement, understanding and progress. The report recommended that secondary schools and colleges ensure they use practical work and scientific enquiry as the key stimulus to develop scientific knowledge, understanding and skills. Crucial to achieving this will be to make sure we have enough good teachers in place and that existing teachers have good access to professional development opportunities so that they can readily update their subject-knowledge and skills. This is supported by SCORE who emphasised in their report the importance of effective teaching for improving the quality of practical work in science.

Recruiting more science teachers

We remain concerned that we are not drawing enough teachers from our top graduates, and find it challenging to attract the necessary number of graduates into some subjects such as science. Latest evidence[4] shows that only 14% of science teachers have a physics degree, 22% have a chemistry degree and 44% have a biology degree. *The Importance of Teaching* White Paper states the Government's intention to provide stronger incentives to attract the best graduates to come into teaching, including science.

Changes to higher education and student finance have been announced by the Department for Business Innovation and Skills. The Department for

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[3] Successful science: an evaluation of science education in England 2007-2010, published January 2011.
[4] School Workforce Census, November 2010.

Education will publish later this year further details of proposals for the reform of initial teacher training. These will be discussed with schools, students, universities and other teacher training providers, before confirming plans in the summer, in time for the recruitment of teachers who start their training in September 2012. The White Paper also reaffirms our commitment to more than double the number of participants in the Teach First scheme so that more schools are able to benefit from the talents of the country's best graduates. The majority of Teach First participants teach the most demanding shortage subjects. In addition, teacher training bursaries are continuing to be paid to graduates in the sciences.

Improving the skills of existing teachers

It is important that teachers and technicians have access to good quality professional development so that they can update and improve their subject-knowledge and skills. This is crucial to good quality practical work, enriching teaching and improving engagement in science subjects. The network of science learning centres (jointly funded by the DfE and the Wellcome Trust) will continue to play an important role in providing teachers and technicians with access to such opportunities.

Science learning centres will complement our more general approach to teachers' continuing professional development (CPD) and leadership training. This will focus on schools taking the lead for the training and development of teachers and creating more practical opportunities for peer to peer training. Giving schools greater autonomy in what they do and encouraging greater collaboration between schools will help ensure improvements in science education. This is consistent with our philosophy that teaching professionals know how best to teach.

At the heart of this approach will be the network of teaching schools[5]. These schools will work with strategic partners, including science learning centres and others who can contribute to improving the quality of science teaching, to offer a range of CPD opportunities for teachers and support staff including technicians. Teaching schools will also need to identify other schools and individuals that have the skills, capacity and willingness to work outside their own school to deliver programmes as well as coaching and peer to peer support. The expectation is that the scale and range of provision will grow as teaching school partnerships evolve.

We will continue to develop the relationship between science learning centres and teaching schools to ensure teachers have access to the highest quality development opportunities.

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[5] The teaching schools prospectus can be found at: http://www.nationalcollege.org.uk/index/professional-development/teachingschools.htm?WT.ad=TK015

Curriculum reform

The Government set out in the Schools White Paper its commitment to give schools greater freedom over the curriculum. As part of that commitment, Ministers launched a comprehensive review of the National Curriculum in England for 5 -16 year olds.

Science is one of four subjects – along with English, mathematics and physical education – that have been confirmed will remain part of the National Curriculum at all four Key Stages; and in the first phase of the review we are drawing up drafts of new Programmes of Study for these subjects.

The review will consider the National Curriculum at both primary and secondary levels with the aim of setting out the essential knowledge that all pupils should acquire in key subjects such as science. The review will be informed by the best available evidence, including evidence about what works in the most successful education jurisdictions in the world. The new Programmes of Study for science will be prepared and available to schools by September 2012, to be taught in maintained schools from September 2013.

The Government is committed to wide-ranging and open consultation on the new National Curriculum. The review was launched on 20 January, together with a Call for Evidence which ran until 14 April. We received over 5,800 responses, including detailed responses from the Royal Society, the Association for Science Education and SCORE. We have also been consulting directly with the science education community to seek their views on the content of the science curriculum. This includes the Institute of Physics, the Royal Society of Chemistry, the Society of Biology, the Association for Science Education, the Royal Society and SCORE. This provided them with the opportunity to stress the importance of scientific enquiry and practical work in science education. The Department led a seminar with a wide range of key stakeholders on 31 March, and SCORE organised a one-off conference on the review on 21 March. Further consultation is planned including events to seek the more detailed views of practising teachers.

Qualifications reform

The Schools White Paper set out the Government's intentions for qualifications reform. New GCSEs will be developed to reflect the outcomes of the National Curriculum review, and specifically to reflect the new Programmes of Study for science. In reforming GCSEs, we will also as the extent to which the ability to undertake effectively practical experiments in laboratory, field and other environments should be specifically assessed through formal examinations.

The Department is working with Ofqual on a new process for developing A levels which gives universities and learned societies a much stronger say in their design and development. A levels should match the best qualifications in the world and assess candidates on the knowledge which universities require them to have. We will look to universities to advise on the extent to which practical experiments and field study should be part of A level specifications in science subjects in future.

DfE support to promote practical science

Some work has been undertaken and is in place to promote greater use of good quality practical work in science lessons at all levels of education. This includes specific projects and programmes supported by the Department for Education to raise the profile of practical science.

The Getting Practical Programme: Improving Practical Work in Science (IPWiS) project was a two year project delivered on behalf of the Department for Education by the Association for Science Education in partnership with the science learning centres, the Centre for Science Education and CLEAPSS. This was in response to concerns raised by the science education community about the quality of practical work being carried out in schools. Its aim was to raise the awareness of the importance of practical work and to improve the quality of practical work in primary and secondary schools. The programme, which ended in March 2011, provided professional development for teachers, technicians and high level teaching assistants. The evaluation of this programme found that it brought about a substantial change in both the use and effectiveness of practical science.

As part of a drive to promote practical work, the Department also contracted with SCORE to produce the *Practical Work in Science* booklets that were sent to all primary and secondary schools in England in 2009. The booklets were designed to help teachers recognise and plan for a wide variety of high quality practical work, including opportunities for pupils to practise specific scientific techniques and procedures.

The network of science learning centres provide science teachers and technicians with a good range of professional development opportunities including courses and events on practical work. The Science Learning Centre website provides access to a whole range of support for teachers including, for instance, the Practical Chemistry webpage which provides teachers of chemistry with a range of experiments from which to choose. The National STEM Centre, funded by the Gatsby Charitable Foundation, is based at the National Science Learning Centre in York. It houses a large collection of resources that science teachers can draw on to support teaching in the classroom.

The DfE-funded online directories of STEM enhancement and enrichment activities provide yet another source of rich high quality programmes and activities that teachers can use.

Health and safety

Although health and safety risks need to be managed, the safety measures adopted should be proportionate, and in most instances will enable rather than hinder activities, thus enabling pupils to benefit from a wide range of experiences.

All schools must adhere to the *Health and Safety at Work Act etc.* 1974 which places a duty on employers to ensure that all staff and pupils are safe; and *The Management of Health and Safety at Work Regulations 1999,* which requires employers to assess the risks of activities such as science lessons and field trips and to put into place measures to control those risks. Currently in relation to some field trip activities (e.g. caving, trekking etc) schools should check that the provider holds a licence from the Adventure Activities Licensing Authority, which manages the statutory inspection and licensing scheme as set up in 1996. Parental consent is advisable for visits that involve any element of the outdoors and, in general, for visits that take place outside the normal school day. Information (without consent) should suffice for less adventurous visits that fall within the school day. In the case of science lessons as well as the HSWA duties school should also look at advice from CLEAPSS, which has a website of information on practical safety measures.

The SCORE *Practical Work in Science* booklets also contained general health and safety guidance; and there are professional development courses on health and safety available through the network of science learning centres.

The Government wants schools to adopt a more common sense approach towards health and safety by reducing the level of bureaucracy involved. We are concerned that too great a focus on health and safety can often stifle school activities, particularly off site educational visits. The Government wishes to encourage teachers to take pupils off-site by making it simpler to do so safely.

The Department for Education published, on its website in February, its response to Lord Young's report *Common Sense, Common Safety* (published in October 2010) following his review of health and safety law and the compensation culture. We are working with the Health and Safety Executive (HSE) on the recommendations that apply to schools.

The Department leads on facilitating school trips in general. This includes new succinct guidance to convey the message that consent is not advisable for most off-site activities that occur during the school day, and to offer a generic consent form for each pupil which can be used, with an opt-out, for the comparatively few visits on which parental consent is advisable. These, and other measures on which we are assisting the HSE, are designed to make risk assessment more realistic for schools, making it easier for science field trips, amongst other off-site excursions, to be undertaken.

Department for Education

10 May 2011

Written evidence submitted by Rosie Clift (Sch Sci 01)

About me: My name is Rosie Clift and I am a secondary school science teacher at Backwell School, near Bristol. I have been teaching for 3 years, before that I spent 2 years teaching outdoor education in a field centre. I have a degree from Cambridge University in zoology and a PGCE from Bristol University. I am passionate about field work and outdoor science, hence I am writing to express my views.

1. How important are practical experiments and field trips in science education? Both are absolutely vital, for various reasons. I list the two most important reasons below:

I) They are fun and are a big part of inspiring people in science.
II) Being fun, it makes learning an enjoyable experience. I believe this should be a big aim of the education system.

2. Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

In my experience, practical work is mostly alive and well. At my school, we are modifying out key stage 3 curriculum to include more practical work. However, GCSE specifications are low on opportunities for practical work and this is restrictive. Time pressure, to teach certain amount of material before the next module exam, also prevents practical work.

Field trips though are non-existent. I have tried to instigate a field trip for A-level biology pupils. The ecology elements of the syllabus demand outdoor learning but we have access to a very limited range of habitats within the school grounds. Students would benefit immensely from learning in new environments and being able to actually see the principles they are required to learn about. The main barrier is the cost of staffing the trip. For example, if 3 teachers are needed to take our cohort of 60 pupils away for 3 days, the school must pay for 9 days of supply cover. The school cannot afford this and so we are declined permission. Another option is to take students away over a weekend. However as a teacher, though I may be paid for the extra time, the weekend would be thoroughly exhausting and I would be expected to return to normal teaching on Monday morning. Thus I would have to work 12 days in a row in an already exhausting job. For these reasons, I will not organise a weekend field trip for my students.

4**. Do examination boards adequately recognise practical experiments and trips?**

Yes. But the timings of modular exams often don't leave enough teaching time. We end up teaching in a time-efficient way which often means reducing the practical elements.

5. What changes should be made?

Schools and senior management need to recognise the importance of outdoor learning. The second step would be to provide schools with enough money to afford to send students and staff on field trips. Perhaps if the money were budgeted i.e. it could only be spent on field trips, then schools wouldn’t be able to side line the money for other things.

Thank you for providing this opportunity for me to express my views.

Rosie Clift

11 April 2011

Written evidence submitted by Jane Giffould (Sch Sci 02)

Practical experiments in school science lessons and science field trips

Background: *Currently a part time Field Officer for Science Education and available for Supply teaching. Supply has been non-existent in the last 1 ½ years due to financial cutbacks. Trained as a Science teacher and have worked at all levels from KS1 to KS4 plus adults including work overseas both in local and international institutions with additional work in technical and teacher training. The first lesson I ever taught as an untrained teacher in a badly equipped school in Kenya was naturally practical as it seemed so obvious that Science was practical.*

1. How important are practical experiments and field trips in science education?

i) Essential.

ii) The old adage: I **hear** and I **forget**; I **see** and I **remember**; I **do** and I **understand,** is still true.
Students learn better by doing as this helps them to understand the work. Practical work can help motivate the less motivated especially those who work better manually than theoretically.

iii) Science requires a range of skills. These are not taught by theory but by doing practical work to both learn and then use those skills.

iv) Science is an investigative subject. Plenty of investigation can now be done on the internet. However students need to have the credibility of their own practical investigations to provide the understanding as well as the interest.

v) Science is about knowledge of the world. Field trips take students out of the confines of the classroom/lab into the big wide world so that they can see and feel the reality of the subject.

vi) Practical work can engender interest, even the awe and wonder, from Reception through to university level.

2a) Are practical experiments in science lessons and science field trips in decline?

Yes.

b) If they are, what are the reasons for the decline?

i) **Health and Safety** issues linked with the blame culture provide a disincentive to do anything that might have a risk.

ii) **Costs** of Field trips provide problems in a cash strapped system.

iii) **Time** to squash everything into an overloaded timetable means that time consuming practical work, especially Field trips can be cut out irrespective of the loss in the benefits of doing them.

iv) **Attitudes** of senior management who are wary of Science and are risk adverse can help decline.

3a) What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips?

Unfortunately H&S has a major effect on people opting out of practical and Field trips. This is linked with the fear of the blame culture that has invaded our country.

b) What rules and regulations apply to science experiments and field trips and how are they being interpreted?

There are a list of rules and regulations on what can or cannot be done. Many teachers and senior management can be scared of this and back out. CLEAPPS will offer advice as to what can or cannot be done and how to do the trickier parts safely. Unfortunately not all are willing to spend time consulting with CLEAPPS. There is also the problem that rules and regulations seem to keep changing making one uncertain as to what can or cannot be done.

4. Do examination boards adequately recognise practical experiments and trips?

Do not do exam work and so have no answer to this.

5a) If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices?

Decline in practical and field work means that students are denied:

i) the skills that they will need later on, this then inhibits their future choices

ii) awareness of the application of the subject such that they are less informed and so less likely to choose Science or Science related subjects.

iii) motivation provided by practical and Field work and so less likely to follow the STEM path.

b) For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

I do not have first hand knowledge but hearsay indicates that they will do less well if they have missed out on practical and Field work earlier on due to less understanding and lack of skills..

6. What changes should be made?

i) Teachers should be trained to do practical work as standard in Science lessons. They should be encouraged to be innovative and not just follow standard procedures.

ii) The Curriculum should make it obvious that practical work is expected.

iii) Assessment should take a lot more notice of practical work and the skills involved.

iv) Field trips should be an integral part of Science.

v) Assessment should contain a part that includes Field trips.

vi) Funding should cover the need for practical work and Field trips.

vii) Rules and regulations should encourage rather than discourage practical work and Field trips.

viii) Parents should be aware of the part played by practical work and Field trips and be ready to query if they are not available.

ix) School management should encourage practical work and Field trips as an integral part of school life.

x) Inspections should expect to see practical work and Field trips as the norm.

xi) There should be ready advice available for those who are not used to practical work and Field trips.

7. Is the experience of schools in England in line with schools in the devolved administrations and other countries?

I do not know.

Addenda:

1. Cross curricular

This topic has been about Science. However practical work needs to abound in all subjects. History becomes more alive when the classroom becomes a Tudor warship and the students have to turn sea water into drinking water. Shakespeare takes on a new turn when DT skills are used to make the island of the Tempest. Real aviation charts link Maths and Geography as students plan flights around the local area. The effects of smoking considered in CPSHE are much more emphatic when the students make their own smoking machines out of household materials.

2. Some examples of successful practicals

a) Year 11 equivalent in Kenya, Flora and Fauna

Having been in the country for 72 hours I started with a Year 11 equivalent group. I was untrained and had low grade A Level as my Science. The syllabus required the study of local flora and fauna. So our first lesson was outside, in the school grounds doing a study of the local flora and fauna. Later on we extended our studies to the Game park which was next door. The students were surprised at doing practical as they had never done any before. 2 years later if a lesson was not practical I had to apologise. It really turned them on.

Equipment: notebooks and local knowledge.

b) Year 11 Physics, Forces

In the days before computers were the norm the technician insisted that I used the computer. A stroppy Year 11 were amazed to watch their results being plotted in real time so that they could see what was happening. Suddenly they were producing a ream of theories as to what might happen if ………. They extended their experiments way beyond what was needed and came up with some excellent answers. With theory alone they could not have done this.

Equipment: Computer, sensor, stand, masses

c) Year 1 Risk Assessment for Nature Study

Being keen to take the Year 1 out regularly I got them to do the Risk Assessments starting with a riverside walk to look at flora and fauna. This made them aware of potential problems and how to sort them out. They came up with more ideas and solutions than I would have done. For any outing they would insist on doing the Risk Assessment.

Equipment: Parents as extra adults

d) Year 8 and Speed

As supply a theory lesson on Speed went practical. Students from a potentially recalcitrant class were given an open investigation to find out about speed. They were surprised when I accepted various trying to be 'clever' answers in a range of units. By the end we had agreed as a class that cm/sec was probably the best set of units for what we were doing. An interested class were made to stop for break.

Equipment: Rulers and stopwatches or classroom clock.

Jane Giffould
ASE Field Officer, Regions 05 and 18

24 April 2011

Written evidence submitted by Professor Edgar Jenkins (Sch Sci 03)

Practical experiments in school science

The background to practical work in school science

1. When physics and chemistry were first schooled in the mid- nineteenth century, examiners complained that while many candidates demonstrated a sound theoretical knowledge of physics or chemistry, most had no experience and therefore little understanding of the practical elements of these disciplines. The last quarter of that century therefore witnessed a 'vigorous onslaught against teaching that was unillustrated by experiment' in an attempt to develop the practical teaching of science and to integrate it with its theoretical aspects. Securing such integration presented problems and these remain in evidence to the present day.

2. Remedying this shortcoming required, as a minimum, the funding, design and building of laboratories designed for practical teaching; over 1,100 school laboratories were built between 1877 and 1902. After 1904, 'practical work in science' was a condition of grant aid, and the position of such work within secondary education has not been challenged to this day. In the case of public elementary schools, however, provision for the practical teaching of science was much more modest and often amounted to little more that a room with a sink and a few plain tables, a legacy that was to survive the transition to primary schooling following the Education Act of 1944.

3. The introduction of the system of School Certificate Examinations at the end of the First World War consolidated the kinds of practical work undertaken in post-elementary school laboratories. Teachers and pupils were supported by a range of practical manuals which set out the way experiments were to be conducted and introduced what was to become familiar to generations of school pupils, the recording of practical work under the stereotypical headings of 'text, observation, inference' or 'apparatus, method, observations, inference, and conclusion'. These headings were intended to train pupils in what was usually referred to as 'the scientific method'. Teacher demonstrations, conducted on a raised demonstration bench, augmented the practical activities undertaken by the pupils themselves. It is to be noted that biology as a school subject owed much to its assumed importance in pre-medical education and it struggled to find a secure place in the curriculum of most grammar and public schools until after the end of the Second World War. Significantly, one of the objections levelled against the subject was that it 'did not lend itself' to experimental work.

4. Little was to change in the form and content of the teaching of practical science in secondary schools until the major reforms of school science curricula in the 1960s. Encouraged by the Nuffield Foundation and the Schools Council set up in 1964, school syllabuses in the three basic sciences were modernised, specialist science teaching apparatus was designed and manufactured, and new approaches to assessment introduced. The emphasis on helping pupils gain an insight into ‘scientific method’ remained: science teachers were now encouraged to teach science ‘by investigation’ and to help their pupils to learn ‘by doing’ and ‘by discovery’. Pupils were told they would become ‘scientists for a day’.

5. The expansion of comprehensive secondary schooling, following the publication of Circular 10/65, along with the introduction of the Certificate of Secondary Education (CSE) in the same year, presented school science teachers with an opportunity to explore anew the contribution of practical work, both within and outside school, to the scientific education of those whom they taught. The evidence suggests that while there was much that was good, there was also much that was not. Part of the problem lay in the requirement to assess pupils’ practical competence for the purposes of an external examination. One consequence of this requirement was an emphasis on assessing allegedly discrete ‘skills’ such as observing, hypothesising, measuring and recording. In such circumstances, the educational purpose of the practical activity was only too easily lost. Much the same problem prevailed in the 1970s when, largely under the influence of developments in the USA, the emphasis came to be placed on science as a set of discrete processes, each of which was judged capable of independent assessment. Taken as a whole, these ‘processes’ were said to constitute the way in which scientific research was undertaken and they represented yet another way of attempting to introduce pupils into ‘scientific method’.

6. The various versions of the science component of the national curriculum introduced after the passage of the Education Reform Act 1988 not only continued, but gave statutory authority to, the role of practical work in helping pupils understand the nature of scientific activity. Successive versions of the science national curriculum introduced new prescriptions and new terminology but the essential purpose was unchanged. The 1989 Statutory Order contained an Attainment Target (AT1) entitled ‘Exploration of Science’, along with another Target (AT17), ‘The Nature of Science’. The latter was effectively dismantled in the 1991 Order which also replaced the AT1 of the 1989 Order by Sc1, ‘Scientific Investigation’, which emphasised individual pupil investigations. Sc1 was to become the single most difficult, and eventually most controversial, element of the Statutory Order for Science. The current Order requires teachers to teach their pupils ‘How Science Works’.

At least four broad lessons might be learnt from this brief historical overview.

- School science education has historically had two broad aims; helping pupils acquire basic scientific knowledge and to gain an insight into the nature of scientific activity. These aims are evident in the current national curriculum, along with other objectives that are considered to necessary to develop ‘scientific literacy’.
  However, there are significant methodological, linguistic, conceptual and philosophical differences between individual sciences and there is disagreement among philosophers of science about some fundamental aspects of how scientific knowledge is sought, gained and verified. Given this, any generic prescription of ‘how science works’ is always going to present problems.

- These problems are compounded by the statutory requirement to assess pupils’ understanding of this element of the national curriculum. There are not only the technical problems of valid and reliable assessment: the different statutory prescriptions of ‘how science works’ or of ‘scientific investigation’ have led to an over-emphasis on practical activities structured around what must be assessed. The result has often been a series of repetitive practical activities of little or no educational merit.

- The nature of practical work conducted in schools has changed over time. The changes reflect developments in the scientific disciplines, the school curricula derived from them and, most recently, the introduction of a statutory national curriculum. The design of laboratories has also changed. Few modern school science laboratories incorporate a demonstration bench, reflecting the decline of teacher-led demonstrations in favour of practical work conducted by pupils individually, in pairs, or in small groups.

- The approach to teaching practical science has been, and continues to be, justified by reference to psychological theories about how young people learn, theories that have not always stood the test of time and which have often relied on evidence that is difficult to relate to the day to day circumstances of practical teaching. Even today, when much more is now known about how young people learn, it is by no means straightforward to relate theories of learning to pedagogical practice.

How important are practical experiments in science education?

7. The preceding paragraphs indicate the abiding importance of practical work in the teaching of school science. There is good evidence that most pupils like and enjoy practical work, particularly when it involves a significant degree of personal autonomy so that they have some control over the planning and execution of their work. It is also not difficult to make a good case for engaging pupils scientifically with the material world and with some of the techniques used to help scientists understand it. However, the importance of practical work can only be judged in terms of its effectiveness in promoting learning. Here, the evidence is problematic. Much of the literature relating to practical work is exhortatory rather than research based and it reflects considerable confusion about the goals of laboratory teaching. These goals include the mastery of subject matter, the development of scientific thinking and of diverse practical skills, the encouragement of interest in science and the promotion of an understanding of 'how science works'. Without a clear statement of what an individual activity is meant to achieve, it is not possible to evaluate its effectiveness. Where small scale research studies have been undertaken, they suggest, for example, that practical work is no more effective than several other methods in helping pupils to learn subject matter and that, in some cases, it leads to confusion rather than to understanding.

8. **Are practical experiments in science lessons in decline and, if so, why?**

There statutory demands of the national curriculum have consolidated the position of practical work in school science. It might be difficult, therefore, to argue therefore that the *amount* of practical work has declined substantially, although some teachers claim that 'pressure to get through the syllabus' has left them less time for practical activity than they would like. The effective organisation and delivery of practical science teaching requires good technical support. The substantial improvements that have occurred in providing such support, together with a recognised career structure, are to be warmly welcomed.

However, there is little doubt that those same demands have also narrowed the *range* of practical work undertaken in secondary schools. In some cases and especially up to GCSE level, they have also produced an over-reliance on tedious, algorithmic exercises devised to meet the demands of assessment. In addition, many worthwhile practical activities that were once commonplace are now unfamiliar to many teachers, especially to the growing number whose experience is confined to working with a statutory curriculum. Teacher-led demonstrations also fell somewhat out of fashion in the second half of the twentieth century, despite the contribution that they can make to pupils' scientific education. Health and safety considerations may also have be a significant factor in the case of some teachers, although the evidence is that many concerns about the risks associated with laboratory activities, equipment or materials are mistaken or exaggerated. There is also evidence that when teachers teach outside their subject specialism, e.g., physics graduates teaching chemistry, they lack the confidence to undertake some forms of practical work with their pupils. The national curriculum has unquestionably led to more science being taught in primary schools and much of this involves hands-on activities that can reasonably be called practical work.

9. **The influence of health and safety concerns**

Science teachers' work is governed by a range of legislation, including the Health and Safety at Work Act 1974 and the COSHH Regulations and Codes of Practice. When the HSWA came into force, some schools, science advisers and local authorities initially over-reacted, for example by removing certain chemicals from schools or limiting the amounts that could be stored. Since then, a more balanced and nuanced approach has prevailed. Most secondary school science teachers have a good grasp of the hazards associated with their discipline and much statutory and non-statutory guidance is available. COSHH assessments are in place for almost all the practical activities likely to be undertaken in school science laboratories, and organisations such as ASE and CLEAPSS offer excellent advice. However, it remains the case that some teachers continue to believe that legislation or LEA guidelines or advice prevents them conducting some kinds of activities or using some materials when neither is the case. Such belief may well narrow the range of practical work that might otherwise be undertaken. As noted above, the difficulties that arise when teachers work outside their subject specialism may further limit what is done.

It is also the case that awareness of the risks associated with some practical activities changes over time, e.g. working with micro-organisms, blood sampling. When such changes occur, it is important that science teachers receive accurate advice and guidance about which activities they may, or may not, continue to undertake with their pupils.

10. **Examination Boards and practical work**

The work of Examination Boards, which now extends beyond that of Examining, is strongly influenced by the demands of the national curriculum and what are perceived as teachers' needs. As commercial organisations, they are sensitive to these needs and they reflect, rather than significantly limit, the kinds of practical work that science teachers are required to undertake.

11. **Practical work, student performance and higher education**

It seems a truism that well thought out and executed practical activities can enrich students' experience of school science. It may also increase their interest in science and their motivation to pursue further study in a STEM subject. However, the factors governing students' choice of subject and of career are complex. They evolve and change over time and the contribution of curriculum and pedagogy is unclear. Well conducted practical work should be one among many different approaches that science teachers can call upon to interest and motivate pupils and to enhance their learning. It is likely that the narrowing of the range of practical work done in schools has led to some reduction in the range of practical competence that could reasonably be expected of those embarking upon an undergraduate course in a STEM subject.

12. **What changes should be made?**

Many science teachers are unlikely to welcome further significant change to their day to day work, but the time may be right for a substantial inquiry into the purpose, form and assessment of practical work in school science, perhaps along the lines of the recent (2006) inquiry undertaken by the National Research Council of the National Academies in the USA. Among the questions that might be addressed are the following. What kinds of practical work are there? What is the purpose of each and what can research tell us about their effectiveness in achieving those purposes? To what extent is practical work a pedagogical tool that has acquired an unjustified dominance in school science education when other tools, including the use of ICT, are readily available? What kinds of practical work might help students gain an insight into what it means to think scientifically and what other ways are available? If practical work is to be assessed, what forms of assessment are appropriate and how might these relate to the requirements of a statutory curriculum? In the absence of a more secure and shared understanding of the purposes, role and effectiveness of *different* kinds of practical work, it will be difficult to move beyond a bland assertion that it is essential to school science education.

In the more immediate term, attention needs to be given to developing and promoting a greater variety of science-based practical activities than is presently the case and clarifying and evaluating what these can realistically hope to achieve. Students can now access large empirical data bases which can be exploited to develop a range of important skills. Remote access to scientific instruments is also possible and the resources of the internet could be more fully exploited. Simulations, teacher or pupil-led demonstrations, also have roles to play in augmenting the more traditional physical manipulation of the physical world through hands-on experiments in the school laboratory or elsewhere. Examples of al these kinds of practical activity can be found in schools but thus far they remain relatively uncommon. There is an important task here for organisations such as the Science Learning and STEM Centres, the professional scientific societies and the Association for Science Education.

13. **The experience of England in an international context**

Experimental and practical work constitutes a highly distinctive aspect of school science teaching and is an element of prescribed curricula in almost all school systems. England, however, perhaps has a longer experience than any other country of pupil-based practical work directed towards helping pupils learn scientific content and understand something of 'scientific method'. It is perhaps significant therefore that a Eurydice survey (2006) revealed that England differs from many other countries within the EU in not prescribing or recommending either science-related project work or teacher demonstrations.

In England as elsewhere, the emphasis on 'how science works' has all too often led to individualistic and intellectually de-problematised practical activities divorced from theoretical studies. At best, these activities distort, and at worst, misrepresent the practice of science. Today, many countries are seeking to promote a more realistic and contemporary account of the nature of science, not just within the laboratory but in the wider social and technological context. However, as noted above, this is a far from straightforward undertaking.

Following the Rocard report, the European Union is allocating substantial amounts of money to support multi-national collaborative projects intended to promote inquiry based science education (IBSE). There are also individual country initiatives, e.g, la main à la pâte in France. In many cases, the multi-national projects involve not only schools, but also museums, institutions of higher education and science teaching organisations. For some countries IBSE represents a significant innovation but all encounter, to different degrees, the problem of accommodating such an approach within prescribed curricula and of reconciling it with the demands of assessment. The effectiveness of IBSE in achieving its goals has also been called into question.

International tests such as TIMSS and PISA shed little light upon the relationship between student performance and the emphasis on practical work in the English national curriculum. Pupils in the UK scored statistically significantly above the OECD average in each of three sub-competences assessed in PISA in 2006 (identifying scientific issues, explaining phenomena scientifically and using scientific evidence). However, more than a dozen other education systems, such as those of Taipei, Finland, Belgium and Australia, were also categorized as statistically significantly above the OECD average, despite the major differences between them.

Edgar Jenkins
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University of Leeds

5 May 2011

Written evidence submitted by Scottish Schools Equipment Research Centre (Sch Sci 04)

SSERC has provided advice and training on safe, exciting, practical science and technology to Scottish schools for over 40 years. The following submission therefore refers primarily to the situation in Scotland.

1 How important are practical experiments and field trips in science education?

Practical work has a central place in science courses. It can be used to aid knowledge and understanding as well as to develop scientific skills. Experimental work can be illustrative, develop problem solving skills in a practical context and provide opportunity for investigative work. It also presents an ideal opportunity to develop the principles of experimental design, something which may require more emphasis in the curriculum. Reliable experiments are an essential part of any science curriculum and the inclusion of these is an important aspect of curriculum design. In addition, experimental work provides real and first hand information for report writing, a skill which extends beyond science but for which science provides the ideal context.

Science is not simply a body of knowledge. It is also a way of thinking, of approaching problems, planning investigative work and evaluating evidence. Many of these skills can only be properly developed experientially, through experiments and observations. Practical, experimental work is part of the scientific method and as such is an essential component of all science courses. Practical work can fulfil a number of educational purposes including:

- ♦ Illustrating science concepts as an aid to understanding
- ♦ Developing competence in practical techniques
- ♦ Generating data for subsequent analysis
- ♦ Testing hypotheses and drawing conclusions
- ♦ Developing skills of experimental design
- ♦ Developing skills and knowledge.

Practical experiments and field trips, therefore, are an essential part of science education for a number of reasons:

1.1 Theory without evidence is dogma, not science. At the core of science is the notion that all hypotheses must be tested. Pupils are not the "empty vessels" of Mr Gradgrind's school as described by Charles Dickens. Some come to science with sound ideas that need developing. Others are full of misconceptions and these misconceptions will remain unless the pupil experiences a real situation that subverts his or her existing ideas. Simply telling children that in the absence of air resistance, all objects fall at the same rate is not effective. They may repeat this information to keep their teacher happy or because they know what is required to obtain a mark in a test, but they will not believe it and any learning that builds on the concept will be undermined. Interestingly, there is anecdotal evidence that pupils are not convinced by video evidence. A class who were shown the experiment where a hammer and feather dropped on the Moon fell together, informed their teacher, "that's been faked!"

1.2 A lot of bad science has come about through conjecture rather than investigation. Aristotle pronounced on the laws of motion and got them wrong. He also claimed that men had more teeth than women. Aristotle was married and could have looked. He could also have experimented on motion, but believed that practical work muddied the waters of pure reason.

1.3 Whilst a number of pupils are interested in science for its own sake, many are only motivated when their learning is set in a real world context. Practical and field work has been shown to be motivating, for example in the research of Rae Stark and Donald Gray [1]. This study asked children in early secondary about their favourite science activities. Top of the list was working with apparatus.

2 Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

In Scotland, this would appear to vary from centre to centre. Where they are in decline, there are again a number of possible reasons:

2.1 Many science departments will cite that not only has their budget not increased in real terms over the past two decades, it has not increased at all, and in a significant number of cases has reduced. There is insufficient money to repair broken equipment and existing equipment is often out of date and ineffective. In our experience science teachers often contrast their situation with that of Business Studies departments where up-to-date IT equipment running the latest software can be found in attractively-furnished computer suites. Clearly investment in ICT facilities can be justified; however failure to maintain credible facilities for practical work across the sciences is an unsatisfactory position for schools and colleges to face in the 21st century.

2.2 Some teachers, feeling under pressure to achieve good exam results for their pupils, see the omission of practical work as a way of creating space in a crowded curriculum for extra exam preparation. In most current examinable courses, practical work is not assessed to any great degree. Consequently, despite its intrinsic value to the education process, many students will have reduced experience of practical work.

2.3 Health and safety concerns may also be a factor. This is discussed below.

2.4 Low exposure to practical work can become self-perpetuating - a number of newly-qualified science teachers will have had limited experience of practical work and will thus be less inclined to incorporate it in their lessons. The role of SSERC in addressing this is discussed below.

3 What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

3.1 All activities in a school science class must be risk-assessed. All Scottish

Local Authority-funded schools and most independent schools have access to generic risk assessments from SSERC which runs a rolling programme of free health and safety professional development for science department managers. The key message is that health and safety is not a barrier to exciting, practical science. Nor should implementation of health and safety policies and procedures be onerous or paperwork-heavy. SSERC runs a free helpline and publishes resources in paper and electronic format. SSERC has worked very hard to dispel rumour and myth associated with health and safety, promoting the view that it is risk-assessing, not paperwork, that prevents harm. SSERC now works in partnership with HSE to promote sensible risk management throughout schools.

4 Do examination boards adequately recognise practical experiments and trips?

4.1 It should be noted that there is only one examining body in Scotland. With the exception of the Advanced Higher Investigation units in the sciences, there is little formal recognition of practical work. The Standard Grade investigations and Learning Outcome 3 tasks in current Higher and Intermediate courses can be reduced to hoops through which pupils are trained to jump by teachers keen to proceed apace with courses. There is hope that the new Curriculum for Excellence Highers have addressed this through Case Studies and Researching Units.

5 If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

5.1 Some students enter Higher Education with few experimental or data handling skills. Industry and the HE sector require skilled technicians. Schools will not be able to meet the demand for such people if the pupils do not experience hands-on practical work. A recent report [2] highlights concerns in the HE sector where 50% of technicians in chemistry, engineering and physics departments are due to retire within the next 15 years. Students who have little experience of practical work will not be well-placed to take advantage of the posts which will become available.

5.2 It is worth going beyond the scope of the question to consider another purpose of science education, which is to develop scientific literacy in pupils who are not destined to follow a science-based career. As adults, these people will be confronted with decisions on matters such as sustainability and medical ethics. The skills of collecting and evaluating evidence, instilled through good practical work, are invaluable here. Field trips are very valuable when it comes to placing learning in a real life context.

6 What changes should be made?

6.1 SSERC has carried out studies into the funding necessary to equip and maintain science departments. The costs are not trivial but the benefits would be immediate.

6.2 SSERC, in partnership with the Scottish Government and other organisations, has developed and run a continuum of experiential professional development based around practical science. This CPD has been independently evaluated and has been shown to be extremely well-received and highly effective in producing real change in the classroom. It is to be hoped that the funding that makes this possible will be maintained. The training covers primary teachers, student teachers, registered science teachers and leaders of science departments. SSERC also runs training on health and safety, where a clear message is given on health and safety not being a barrier to practical work. SSERC's infrastructure allows for continuing support to those involved in Scottish science education at all levels. The new Higher courses place greater emphasis on research skills. These areas will also require the provision of support for teachers and again, SSERC is well-placed to provide that support.

7 Is the experience of schools in England in line with schools in the devolved administrations and other countries?

7.1 It is likely that the situation in Scotland is less severe than that in England as virtually every teacher in a Scottish science department is a subject specialist. School science technician services are more highly structured. Support staff have a range of accredited professional development available to them, offered through SSERC and partners.

Declaration of Interest

SSERC is a not-for-profit research and advisory body funded by all Scottish local authorities, most independent schools in Scotland and a number of further education colleges. The organisation was set up more than 40 years ago to give advice and training to schools on safe, effective practical work. Since the middle of the last decade, SSERC, supported by the Scottish Government, has worked with partners, including the National Science Learning Centre, to develop and deliver a continuum of professional development for student teachers, probationer teachers, registered teachers, subject leaders and technicians. Additionally, SSERC's advisory service has expanded from supporting primary and secondary school science and technology to take in aspects of whole school health and safety. SSERC staff continue to be involved in advising all current curriculum development groups in Scottish school science.

Scottish Schools Equipment Research Centre

6 May 2011

Written evidence submitted by the British Science Association (Sch Sci 05)

SCIENCE EXPERIMENTS

Introduction

1. The British Science Association is a registered charity that exists to advance the public understanding, accessibility and accountability of the sciences and engineering in the UK.

   We seek to achieve that by connecting science with people: promoting openness about science in society and affirming science as a prime cultural force through engaging and inspiring adults and young people directly with science and technology, and their implications.

   Established in 1831, the British Science Association organises major initiatives across the UK, including the annual British Science Festival, National Science and Engineering Week, programmes of regional and local events, and an extensive programme for young people in schools and colleges.

   The British Science Association is established under Royal Charter and governed by a Council which forms the Board of Trustees. It is registered with the Charity Commission (number 212479) and with the Office of the Scottish Charity Regulator (number SCO39236).

How important are practical experiments and field trips in science education?

2. The benefits of practical work are well documented and were summarised in the **SCORE** (2008) report[1] which stated "practical work promotes the engagement and interest of pupils as well as developing a range of skills, science knowledge and conceptual understanding".

3. The OECD-wide **PISA** studies provide compelling evidence of the value of practically-based activities[2]. They show that involvement by students in enrichment activities such as science fairs, competitions and visits is one of only three 'educational resource factors' correlated with increased performance in science after allowing for socio-economic background.

4. Practical activities and field trips offer particular opportunities for young people to develop creativity. Creative activities, according to the report of the National

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[1] Science Community Representing Education (2008) *Practical Work in Science: A Report and Proposal for a Strategic Framework*, Royal Society, London

[2] PISA 2006: Science Competencies for Tomorrow's World, Vol. 1, pp258-264 and Executive Summary pp43-44

Advisory Commission for Creative and Cultural Education (the **Robinson** report[3]), have four characteristics (which are used by Ofsted inspectors to report on creativity in schools), namely: being imaginative and purposeful, and developing something original and of value in relation to the purposeful objective. That implies the need for contexts that offer opportunities for exploration, for taking risks and making mistakes, provide exciting or unusual stimuli, sharing and reflecting openly on ideas, respecting difference and offering choice and control to students.

5. We believe strongly that young people should experience science and technology by engaging in exploratory and open-ended scientific and technological activities themselves. 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.

6. Our **CREST Awards scheme** was externally evaluated recently by Liverpool University[4]. The findings from the impact study showed that:
   - CREST has a strong positive impact on its primary target audience
   - Students gained knowledge and developed transferable skills
   - Students' attitudes towards STEM and aspirations for STEM careers were improved
   - A large number of teachers commented that CREST enthuses and motivates students and many commented on the skills and confidence that students develop
   - Many teachers felt that the scheme helped inform their teaching and gives students a broader experience of STEM than school alone can offer
   - Teachers felt that CREST raised the profile of STEM in the school
   - Mentors highlighted the impact on students' decision-making at Gold level, and described the impact on young people's subject choices at university.

7. The British Science Festival (organised by the British Science Association) also provides inspirational hands-on practical experiences for young people outside the classroom, reinforcing our organisation's dedication to these principles.

8. The Association manages the National Science and Engineering Competition and is a major partner and instigator of the Big Bang (UK Young Scientists' and Engineers' Fair).

Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

9. The British Science Association is particularly interested in the level of opportunities for project-based practical work in schools and colleges. We believe this is in decline despite on-going curriculum developments encouraging this approach. Based on ad hoc feedback, possible reasons contributing to a potential decline include:

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[3] http://sirkenrobinson.com/skr/pdf/allourfutures.pdf

[4] Grant, L. (2006) *CREST Awards Evaluation Impact Study*, University of Liverpool

- Discrete STEM experiences are easier to implement initially whereas project-based approaches may be more time consuming and problematic.
- Investigative project work is used mainly for assessment purposes (as shown by Millar and Abrahams (2009) [5], who observed 25 practical situations in schools as part of their study, none of which came under the category of supporting the processes of scientific enquiry).
- Teachers sometimes feel that the benefits of project work regarding attainment are not proven or not always recognised.
- Teachers have prioritised implementing new curriculum changes and have not yet had the time to incorporate project-based approaches that effectively support these changes.
- Teachers may be less motivated to implement project-based practical experiments since they feel it can be difficult to find experiments that are both exciting and achievable, as reported in an independent evaluation of the CREST Awards carried out by Grant (2006)[6].
- Today's teachers have developed through a structured curriculum and are not as experienced in implementing project-based approaches.

10. Reports such as NESTA's Real Science[7] have investigated the status of science enquiry in UK schools, but given this was produced in 2005 and that educational policy now further encourages schools to offer project-based and cross-curricula approaches to practical work, it's crucial that we find out whether genuine experimentation by pupils is actually getting less common, not more, in schools and colleges.

Do examination boards adequately recognise practical experiments and trips?

11. As an organisation focusing primarily on informal learning opportunities we are not best placed to comment on this in detail. However, we do recognise the difficulties in employing fair models that uniformly assess practical work as part of exams. A variety of techniques have been used by examining bodies (e.g. ISAs, IAA tasks) but anecdotal comments from teachers suggest that some may look for the easiest way for students to safely score the best marks (rather than choosing the assessment approach that may provide the best opportunities for students to develop a broad range of practical skills) given the emphasis on league tables and results. We are very interested in the development of new qualifications recognising the importance and value of longer term project work (which is often practically based) such as the Extended Project Qualification, which echoes the ethos of CREST and the principles of the British Science Association.

If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example,

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[5] Abrahams, I. and Millar, R. (2009) Practical Work: making it more effective. *School Science Review*, 91 (334), 59-64.

[6] Grant, L. (2006) *CREST Awards Evaluation Impact Study*, University of Liverpool

[7] http://www.nesta.org.uk/library/documents/RealScienceFullReport1.pdf

what effects are there on the performance and achievement of pupils and students in Higher Education?

12. Our own small scale research with admissions tutors in HE has suggested that students often arrive at the start of their course without the skills set to persevere and problem solve in longer term project-based work. This could directly relate to the lack of opportunities for such practically-based project work that students undertake in schools/colleges and this reinforces our belief in the value of the CREST Awards.

13. Generally there is a low awareness of the breadth of careers that may result from science/maths routes. Similarly there is a low awareness of the rewards and opportunities that may be available through STEM careers.

14. High quality enhancement and enrichment is very important to improve engagement with role models and scientists helping to remove stereotypes and playing a key part in enthusing young people. Learning does not just take place in lesson time and young people can benefit from having a wide range of learning experiences in different environments outside of the classroom and through field trips. These principles are firmly supported through the CREST Awards scheme.

What changes should be made?

15. A radical change is not required since it feels as though teachers (and students) have had to deal with an ever-changing curriculum. We would suggest there should be more of a change of emphasis, to be gradually implemented which will take time if it is to be effective.

16. New curriculum developments should not just focus on ‘what’ is included, but more of a consideration should be given to ‘how’, providing space for creativity and the development of broader skills. However, if teachers are to be encouraged to broaden their approaches through a more open curriculum then it needs to be recognised that appropriate support will be required and it will take time (and resources) to effectively implement any change of emphasis in a new curriculum.

17. There is a wide range of organisations that are well-placed to help teachers provide their students with opportunities to do practical work and take part in field trips and visits. These organisations range from national bodies like the British Science Association, the Association for Science Education, the various professional bodies and STEMNET through to small local organisations that work with a small number of schools more intensively. These organisations are facing considerable turbulence at the moment as a result of reductions or disruptions in their funding streams. While this may be an inevitable consequence of the Government’s current spending priorities, we need to ensure we don’t inadvertently lose a swathe of experienced activity providers who can help to safeguard the future health of the UK’s R&D base.

    One of the key themes that emerged from the most recent meeting of our CREST Quality Assurance Group was that primary schools continue to request intensive support from our partner organisations (those who provide activities for schools). Primary teachers tend to recognise the value of hands-on, practical activities in stimulating interest in the sciences – but because so few primary teachers have science backgrounds, they often lack confidence, which is why they value the support from us and our partners. We need to ensure that, despite the challenging funding situation, teachers in primary and secondary schools continue to have access to providers of high quality practical activities and field trips that encourage children's interest in the sciences.

18. Finally, one of our activity provider partners has commented that with the loss of the STEM Advisory Forum from April 2011, there is no longer a channel through which providers of practical activities, field trips, etc. can voice their opinions.

Is the experience of schools in England in line with schools in the devolved administrations and other countries?

19. We can use the numbers of CREST Awards achieved by secondary students as a proxy for the amount of practical work going on in schools across the UK. In 2008, Northern Ireland students achieved 5461 Awards which was 21% of the total number achieved in the UK, despite only having 3% of the UK's population of 10 to 19-year-olds[8]. A similar phenomenon, though less exaggerated, can be observed in the figures for Wales and Scotland which may suggest that schools in devolved administrations are able to offer more practical work opportunities to their students. Any such conclusion would require further research though, since perhaps students in England are being offered practical work opportunities outside our programmes.

Declaration of interests

The British Science Association is in receipt of grant funding from the Department for Business, Innovation & Skills and the Department for Education towards the CREST Awards programme and from the Department for Business, Innovation & Skills for the National Science and Engineering Competition.

British Science Association

6 May 2011

[8] Figures taken from Office for National Statistics http://www.statistics.gov.uk/statbase/Product.asp?vlnk=15106

Supplementary written evidence from the British Science Association (Sch Sci 05a)

At the evidence session this morning, the Chairman raised the question of independent school participation in the National Science and Engineering Competition at the Big Bang, and I gently disagreed with his picture of overwhelming private school participation.

Here are the figures from this year, which show majority state school participation, though some over-representation from the private sector (as one might expect given their larger resources), and from selective schools (including state grammar schools).

71% of finalists came from state schools with 29% from the independent sector. The state schools included comprehensive schools, sixth form colleges, academies and maintained schools.

55% of finalists came from non-selective schools, compared to 45% from selective schools.

The tables below show breakdown by country and selectivity.

	Total	**Total %**
England - Maintained	69	45
England - Academies	13	8
England - Independent	36	23
England - Colleges	3	2
Northern Ireland	9	6
Scotland	14	9
Wales	9	6
Home Educated	1	1

	Total	**Total %**
Total Selective	69	45
Total Non-Selective	84	55

Sir Roland Jackson
Chief Executive
British Science Association
29 June 2011

Written evidence submitted by the Earth Science Teachers' Association (Sch Sci 06)

The Earth Science Teachers' Association is a UK-wide teaching association with some 500 members, most of whom are engaged in teaching A-level or GCSE geology but are mostly also involved in secondary science education. ESTA members also teach in primary schools and in geography departments as well as in teacher education and Higher Education. ESTA was formed as the Association of Teachers of Geology in 1967 and since then has been supporting teachers of Earth science and geology, the Earth science/geology curriculum and the wider teaching of Earth science across the nation.

1. How important are practical experiments and field trips in science education?

ESTA has worked for many years in collaboration with the Earth Science Education Unit which brings practically-based Earth science workshops to trainee teachers and practising science teachers across the UK, through a team of regionally-based facilitators in England, Scotland and Wales. The wide range of practical activities has proved very popular with both practising and trainee science teachers at primary and secondary level, and research carried out by the ESEU has shown that the activities are widely used in schools following ESEU visits (King and Lydon, 2009). Teachers who have used the activities have responded that they have 'brought the lesson to life' and made the lessons much more engaging and understandable to students.

Fieldwork is and always has been an underpinning part of geology education as evidenced by the fact that the GCSE geology specification and the two A-level geology specifications all strongly recommend fieldwork. ESTA members argue that students can not gain a proper understanding of Earth science without engaging with rock exposures in the field, and applying the methodology of geology to understanding the geological settings of the rocks they examine. This not only involves a number of skills unique to geology fieldwork, but also develops wider thinking and investigational skills as well as all the social skills associated with working in the field. Many geology teachers of all levels would argue that it is impossible to gain a proper understanding of how geology is studied, and what geologists do and find out, without experiencing fieldwork. Many also note that their own interest in geology was sparked by a fieldwork experience during their own education, and that we should continue to offer these experiences to spark and maintain interest in the geologists of the future, as well as in the wider population. The emphasis on the fieldwork may underpin the recent increase in geology exam entries at all levels, recorded by King and Jones (2011).

2. Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

ESTA members have anecdotally reported increasing difficulty in being able to undertake fieldwork, for the following reasons:

- the 'rarely cover' regulations which mean that schools find it more difficult and expensive to cover the lessons of teachers taking fieldwork during school time;
- increased emphasis on health and safety regulations, meaning the arranging of fieldwork has become much more time-consuming and paper-intensive than previously;
- specifications in science that are very time consuming, particularly those with some forms of practical assessment, leaving little time for fieldwork;

- the need to argue for fieldwork to be supported within all the other broader curriculum constraints that operate in schools and colleges;
- increasing expense.

3. What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

Anecdotal evidence over many years has shown that authorities respond to increasing health and safety concerns by increasing paperwork, when a much more effective method might have been to invest in professional development that would train the teaching workforce to anticipate and cope with potentially hazardous fieldwork. This would have had the effect of releasing teachers to lead more effective fieldwork, rather than being a disincentive to leading fieldwork. Further anecdotal evidence indicates that some schools and colleges have much more effective policies and procedures for facilitating and supporting fieldwork than others.

Had there been recognised certificated courses for leading fieldwork and funding for teachers to attend these courses, the effect would have been more effective and probably less hazardous fieldwork, and a much wider understanding of the benefits of fieldwork coupled with many more fieldwork experiences being available to pupils. Such courses would have been of real benefit to trainee and practising science teachers alike. The lack of such courses over many years, despite efforts by ESTA and other teaching organisations interested in fieldwork, has been a continuing disappointment. It represents a failure of our education system to engage and inspire students in ways that could have transformed their lives, and which would have had impact far beyond the confines of science.

4. Do examination boards adequately recognise practical experiments and trips?

As noted above, both GCSE Geology and the A-level Awarding Bodies all strongly recommend fieldwork. However, this is not the case with GCSE science examinations. The case for outdoor science would be much stronger if GCSE science awarding bodies supported outdoor science activities more strongly.

5. If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

Recent evidence has shown that 45% of the applicants for UCAS undergraduate courses in geology have studied A-level geology or Scottish Higher geology at school. Many of these will have been inspired to take up geology in the first place, and then to continue studying geology through Higher Education, by fieldwork.

6. What changes should be made?

A nationally recognised and accredited fieldwork leadership course should be devised that would focus on the leadership of effective investigational fieldwork and how this should be implemented most successfully and in the safest and most healthy ways. Such a course should be well supported and funded as well as being broadly applicable to all school-level fieldwork. By the investment of relatively small amounts of funding to such an initiative, the fieldwork experiences of students across the country could be much more widespread and even more effective than they are today.

Meanwhile the Science and Technology Committee should encourage further developments in school level fieldwork through:

- highlighting to all those involved in education the benefits of fieldwork shown by research;
- reducing the hurdles to the implementation of fieldwork in schools and colleges;
- encouraging Awarding Bodies to raise the profile of fieldwork in their science specifications and their assessments;
- encouraging the development of fieldwork education in teacher education institutions and CPD courses for practising teachers;
- encouraging further research into the impact of fieldwork on student learning, motivation and career aspirations, and into the initiatives outlined above
- instigating cross-school subject support for fieldwork, involving, science, geography, history, etc.

7. Is the experience of schools in England in line with schools in the devolved administrations and other countries?

Feedback from ESTA members in Scotland, Northern Ireland and Wales gives a very similar perspective to that described above, with the same issues and constraints. This is not surprising as in England, Wales and Northern Ireland at least, teaching is to the same specifications (in science and geology) so it is not surprising that the issues are similar.

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Earth Science Teachers' Association

08 May 2011

Written evidence submitted by the Field Studies Council (Sch Sci 07)

Introduction

The Field Studies Council (FSC) is delighted that the Science and Technology Committee have chosen to undertake an inquiry into the practical experiments in school science lessons and science field trips. The FSC is the UK's only education charity that specializes in field studies, working every year with over 3,000 school groups and 125,000 visitors to its national network of 18 Field Centres.

The FSC's science related provision includes:

- Fieldwork courses for 550 groups and 23,000 students studying mainly secondary science;
- PGCE fieldwork training courses for students from over 30 colleges;
- Hosting bioscience courses for universities;
- Delivering outreach projects such as *London Outdoor Science* and *Schools in the Parks*, to support secondary schools in Inner London to carry out fieldwork in local parks and open spaces;
- Providing 240 natural history courses for adult professional and leisure learners in field skills such as habitat assessment, field surveying and identification;
- Employing 140 teaching staff and over 200 Associate Tutors, many with bioscience and environmental science degrees;
- Publishing over 140,000 guides and resources to support fieldwork;
- Campaigning with partners such as Association for Science Education (ASE) to support science fieldwork;
- Being a founder member of the ASE's Outdoor Science Working Group;
- Managing the Learning outside the Classroom Council's Quality badge for the fieldwork sector.

The FSC believes that this experience gained over nearly 70 years in the UK gives it a unique insight into trends and influences in science fieldwork and field trips. All of the following evidence is based on FSC's own experience and data sources. Published references are quoted, but all other observations are supported by FSC unpublished but attributable data.

Are science field trips in decline? If they are, what are the reasons for the decline?

General

1. A review of 13 published surveys – including FSC published data – highlights a decline in fieldwork provision in the UK between 1963 and 2009 (ref. 8)

2. FSC's view (derived from long-term membership of organizations such as Institute for Outdoor Learning, English Outdoor Council, Association of Field Studies Officers, Association of Heads of Outdoor Education Centres) is that there has been a reduction over 40 years in the capacity in residential centres to offer taught upper secondary science fieldwork, mainly due to a shift in capacity from field centres (with a secondary fieldwork focus) to outdoor education centres (often with a primary adventure focus)

3. Current national capacity to teach high quality science fieldwork (remote residential and local day) is under continuing threat. In 2011, over 72 field and outdoor education centres are either closing or are 'threatened' by current funding reviews, 66% being Local Authority Centres. Together, these have a combined visitor base of 310,000 primary and secondary pupils

<u>Field Studies Council</u>

Trends in residential fieldwork

4. Science field courses in FSC residential Centres have been in decline for 30 years, both in terms of number and in duration

5. Secondary science groups in have been replaced in FSC Field Centres by geography groups (54% of FSC groups in 1970 were science; 36% in 2003)(ref. 14)

6. Post Curriculum 2000, the ‘modular’ teaching of science A level has sharply constrained the months in which science A level fieldwork is taught, often squeezing fieldwork and field trips into 3 months of the academic year (July, September, October).

7. The average FSC A level science residential field course has halved in length in 15 years, from just under 7 days to 3.4 days (ref. 9). This trend is continuing today.

8. Shortening of courses leads to schools travelling shorter distances to carry out fieldwork, reducing the opportunity to visit contrasting and potentially inspiring locations such as seashore, moorlands and montane habitats. The dramatic decline in opportunities to visit such locations has also been published elsewhere (ref. 7)

9. The decline in FSC residential A level biology courses has accelerated recently, with a fall of 18% recorded between 2008-2010. The reasons given for this decline by FSC Heads of Centres are:

   a) Lost groups (36 lost) not being replaced by new ones (22 gained) in 2008/2009;

   b) New groups staying for shorter periods (3.3 nights compared to 4.5 nights);

   c) Existing groups dropping 1 or 2 nights of their stay

   The reasons given by visiting teachers for these changes (in declining importance) are:

   d) Loss of coursework at A level;

   e) Declining support for science teachers wanting to do fieldwork from school colleagues, including Head of Departments and senior managers – often linked to the demise of coursework and consequent ‘devaluing’ of fieldwork’s importance;

   f) Schools moving fieldwork from remote residential to local day activity OR a total loss of fieldwork (sometimes replaced by laboratory practicals);

   g) Percieved overall cost of fieldwork (particularly increasing transport costs and supply cover costs (see h below));

   h) A narrow interpretation of the ‘rarely covers’ guidance in the teachers workforce agreement which has resulted in increasingly complex timetabling and planning, and increasing cost for supply cover.

10. The decline in UK residential fieldwork, including FSC hosted, is also being replicated in universities, where a general decline in whole-organism biology, modular teaching and the growth of subject content in molecular and cellular biology are often cited as causal factors (ref.13)

Trends in non-residential fieldwork

11. Surveys carried out during the FSC's *London Outdoor Science* and *Schools In The Parks* projects, which aimed to develop use of inner London parks and open spaces by science teachers in local secondary schools, show that a minority of secondary science departments in inner London schools use local parks and open spaces for science fieldwork, with fewer than 20% of schools carrying out GCSE science fieldwork locally (ref.4)

12. The main barriers and issues raised by 47 secondary teachers in the FSC's *London Outdoor Science* and *Schools In The Parks* projects were (in diminishing order): 1) Disruption to classes and other teachers; 2) Staff cover; 3) Health and Safety; 4) Lack of access to suitable site; 5) Perceived lack of usefulness re. curriculum (refs. 4 & 5).

13. An FSC survey of 36 Secondary Science PGCE students from two leading university initial teacher education courses (working with the FSC *Schools In The Parks* project) have also cited similar barriers, as shown in the table below. Nearly a third cited 'School Systems' as being the main prevention to completing outdoor activities with their classes in the future. This included lack of support from mentors, administration, bureaucracy, permissions, and attitudes of the school to outdoor learning.

Response	**Total number of responses**
School systems *	22
Pupil behaviour	14
Timetable issues	8
Location of park near to school	7
Health and Safety**	7
Weather	6
Confidence	6
Other***	2

14. FSC's work in urban areas throughout the UK has consistently shown that primary schools are much more likely to use local parks, open spaces and resource centres for fieldwork compared to secondary schools. There is a precipitous decline between upper primary (KS2) and lower secondary (KS3). Inflexible timetabling is often cited as a major barrier to secondary provision (see paragraph 13 and 14).

The role of teacher training

15. FSC work with partners, including through the ASE's Outdoor Science Working Group (ASE OSWG), has consistently identified that there is a shortage of secondary science teachers with the confidence, competence and commitment to lead fieldwork. In response, the ASE OSWG has released two reports which have made recommendations to remedy this shortage (refs 10 & 11).

16. Any reversal in the decline in science fieldwork will have to be led by teachers. The capacity and enthusiasm to teach science in the field will need to be increased and ensuring a high status for fieldwork in Initial Teacher Training and the standards which underpin it will be the most effective way of equipping future teachers of science with the skills to take their students into the 'outdoor classroom'.

How important are field trips in science education?

17. A review of Outdoor Learning commissioned by the FSC shows that science fieldwork which is well planned and effectively delivered will have positive impacts on cognitive development, personal/social skills and physical development (ref. 12).

18. Another review by the Institute of Education of residential fieldwork courses (combined with adventure activity) at FSC centres undertaken by inner-London secondary schools showed that pupils had increased positive impacts in the following developmental areas: cognitive; interpersonal and social; physical and behavioural (ref. 1)

19. Teachers working with the FSC also note that the experience of using 'messy' primary data outside the classroom (ie. less easily sanitised, managed and orderly than its indoor or virtual equivalent) is very powerful in demonstrating the real strength of scientific methodology (How Science Works).

What part do health and safety concerns play in preventing school pupils from going on field trips? What rules and regulations apply to field trips and how are they being interpreted?

20. Health and safety concerns are cited as important by science teachers and PGCE students , but often less important than other barriers such as inflexible timetabling, lack of cover, lack of training etc. (see paragraphs 12 & 13)

21. Not surprisingly, there is a contrast between importance attributed to health and safety between teachers who are leading their own fieldwork and those who are using 'external' experts such as FSC. Over half of teachers using FSC Centres report that Health and Safety has no negative influence on their decision to offer fieldwork (ref. 14)

22. The ways in which rules and regulations are applied vary considerably between Local Authorities, between schools in the same Local Authority, and even between departments in the same school. Science departments in London secondary schools will cite H&S as a barrier even when history and geography teachers are content to lead residential trips, even overseas

23. The FSC welcomes many of the findings of Lord Young's Review and his proposals to simplify the process that schools and other organisations undertake before taking children on outdoor learning experiences

Do examination boards adequately recognise science field trips?

24. The status and nature of field trips in secondary schools are very much determined by national curricula and specifications: this affects the views of teachers, examiners and inspectors

The influence on teachers

Levels of fieldwork

25. Fieldwork has not been compulsory in the national curriculum for science, unlike geography. As a result, geography numbers have grown within the FSC over 20 years, replacing science as the major contributing subject to FSC visitor numbers (ref. 14)

26. Geography teachers are twice as likely to do residential fieldwork at Key Stage 3, and ten times more likely at GCSE level; they were also twice as likely to do local fieldwork at both levels (ref. 14)

27. In some years FSC sells more plant and animal identification charts to geography teachers than to science teachers – probably because geographers are doing more habitat related (environmental geography) fieldwork than their science counterparts

28. The heightened profile in specifications such as Edexcel SNAB A level biology can increase the take up of fieldwork by biologists. In a 2001 telephone survey carried out by FSC of secondary teachers in 75 state schools who did not use FSC centres the proportion doing A

level biology fieldwork ranged from 62.5% in one specification to 100% using the Edexcel specification (ref.14)

29. Another recent FSC example of curriculum having an immediate impact on levels of fieldwork provision is provided by GCSE Geography where the introduction of Controlled Assessments has led to a sharp rise in GCSE Geography groups

30. However, compulsion is not the only reason for differences in level of fieldwork provision across subjects. Fieldwork seems to be embedded more strongly in the culture of some subjects. For example, the Key Stage 3 history curriculum does not include compulsory fieldwork and yet a 2004 FSC survey of London secondary schools showed that 3 times as many history groups embark on residential fieldwork compared to science groups from the same schools

Nature of fieldwork

31. Whereas secondary geography teachers see fieldwork as being integral to the whole course (the most important reason they cite for continuing to do fieldwork), many science teachers have a much narrower view of its purpose – seeing it as an activity which delivers a discrete part of the curriculum (usually ecology related, and often with a very tight focus on data collecting, handling and analysis, and associated skills and techniques) (ref. 14)

32. These differences in perception result largely from curriculum design which assigns fieldwork to a particular unit in the science curriculum (particularly when it became very closely linked to A level coursework after *Curriculum 2000*) whereas it reoccurs throughout the whole geography curriculum.

<u>The influence on inspectors</u>

33. The statutory requirement for fieldwork in geography also raises the profile of fieldwork in Ofsted subject inspections in schools. Previous FSC research has shown that geography subject inspections have been eight times more likely to comment on fieldwork than science subject inspections. This will influence the importance attributed to fieldwork by teachers and managers (see paragraph 34 below) (ref.14)

<u>The influence on senior managers</u>

34. At a meeting of A level Biology Chief Examiners hosted by FSC the group strongly supported the view that the profile of fieldwork in schools is driven very strongly by external inspection... “if it’s not inspected, it’s not important” (ref. 3)

35. Teachers who have cancelled FSC field courses have cited the perceived lowering of fieldwork’s importance in the eyes of senior managers and departmental colleagues – the fact that it is no longer essential (because coursework was no longer a requirement for example) – as one of the main reasons to cancel (see paragraph 10e)

<u>Influences on socio-economic accessibility</u>

36. Compulsion also support attendance by a broader socio-economic grouping of students. In some FSC projects, for example working with KS3 and GCSE groups from disadvantaged urban City Challenge schools (2009-2010) up to 80% of the 14-16 year olds had never been on a residential in their school careers (and neither had their parents)

37. The probability that a stronger curriculum requirement can lead to a more inclusive take up of fieldwork is supported by FSC data: 75% of geography groups come from State funded schools, compared to 68% of Science groups

<u>If the quality or number of field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education.</u>

<u>General</u>

38. Fieldwork trends are being replicated in undergraduate bioscience degrees (see paragraph 11 above (ref. 13)

39. This is reducing the number of bioscience graduates available (to FSC and others – see paragraph 38 below) to pursue professional vocational careers in ecology throughout the UK (ref. 6)

40. The reduction in fieldwork will also lead to a decrease in exposure to a range of data handling scenarios and the development of associated skills which are highly valued by employers (and identified as a current weakness) including the FSC. See also paragraph 15 above

41. The low level of fieldwork training in Initial Teacher Education and CPD is failing to sufficient numbers of science teachers with the confidence, competence and commitment to lead fieldwork. See also paragraphs 12 & 13 above (refs. 10 & 11)

<u>Field Studies Council</u>

42. The decline in fieldwork experience is reducing the number of bioscience graduates with practical fieldwork skills, thus reducing the pool of potential tutors recruited by the FSC

43. One area in which the demise of practical fieldwork has had a noticeable effect on A level students and trainee teachers is in field surveying and identification skills (ref 2) (research carried out in FSC centres)

<u>What changes should be made?</u>

44. The FSC recommends that the following changes are needed to ensure that the full potential of fieldwork is developed in the science curriculum:

    a) Fieldwork should be a **statutory or strongly stated requirement** in the science (particularly upper secondary) curriculum;

    b) **School inspections** by Ofsted should comment on the level and quality of fieldwork being taught in schools, and it should be a requirement for school science departments to achieve good or outstanding status;

    c) Any reversal in the decline in science fieldwork will have to be led by teachers and we feel that the **Qualified Teacher Standards** (which are currently the subject of Sally Coates' Independent review) should include a requirement for all trainee science teachers (including chemists and physicists, as well as biologists and earth scientists) to have prepared and taught at least one fieldwork lesson as part of their training;

    d) **Career progression** in science teaching should recognize the value of fieldwork experience, including the role of teachers in training colleagues to build school capacity;

    e) Awarding Bodies should adopt **assessment methods** which are appropriate for fieldwork, rather than formulaic summative tasks which diminish its potential;

    f) Guidance to schools should clearly state that the **pupil premium** can be used for fieldwork to proved equitable access by all students to the full range of effective science teaching and learning approaches.

<u>Is the experience of schools in England in line with schools in the devolved administrations and other countries?</u>

45. FSC has Field Centres in Northern Ireland (1 centre), Scotland (1 centre) and Wales (4 centres) as well as England (12 centres). Our very strong evidence is that the trends described above are happening throughout the UK. For example, in 2002 FSC took over Kindrogan Field Centre in Scotland following many years of continuing decline in school and HE visits

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Field Studies Council

9 May 2011

Supplementary written evidence submitted by Field Studies Council (Sch Sci 07a)

The Field Studies Council (FSC) was delighted to have the opportunity to give oral evidence to the Science and Technology Committee on 29 June2011. Due to the time constraints of the session I felt that there were a number of issues which I was unable to fully bring to members attention. We have, therefore, pulled together this short document to expand on our oral evidence and would be most grateful if members of the committee would take a moment to read its contents.

Professional Standards for Teachers

I raised the point about the weakness in the professional standards for teachers in relation to outdoor science but didn't have time to fill in the detail. The current standards are presented at 5 levels:

1. Qualified Teacher Status
2. Core
3. Post Threshold
4. Excellent Teacher
5. Advanced Skills Teacher

Standards for out-of-school learning fall within the section labelled Teaching Skills – the Learning Environment. There are standards for The Learning Environment at QTS and Core levels, but no further professional development after that. In other words an AST is only expected to achieve the same standard as a QTS or C Teacher. The Learning Environment is the only teaching skill that isn't developed (unlike Planning, Assessment, Teamwork etc.) above Core level.

Without an obvious professional development underpinned by explicit standards, prospective PTs, ETs and ASTs won't value CPD courses associated with Teaching Skills – the Learning Environment as highly as the other areas. It sends the wrong message about this area of competency being valued.

The FSC supports a main recommendations in the Outdoor Science report recently published by the ASE's Outdoor Science Working Group which calls for 'more experienced teachers to demonstrate their own role in providing fieldwork training for colleagues in other departments and schools (including across age phases and transitions).'

Initial Teacher Training

Another recent development (since the committee's call for evidence closed) is very worrying. Paul Cohen of the TDA referred to the current review into Professional Standards. The first drafts to emerge from this review show that any reference to learning in out-of-school contexts has disappeared completely from the teaching skills section (even at QTS level). This will represent a big setback for those of us who would like science teachers to develop skills which will enable them to employ the full range of teaching and learning approaches available, both inside and outside the classroom.

It is almost impossible to imagine how the current levels of professional development in teaching in out-of-school contexts will be improved when the standards are weakened, allied to the fact that a growth in number of initial teacher training locations could make inspection and monitoring even more difficult.

The FSC strongly recommends that the reference to learning in an out-of-school context should be retained in the QTS standards, and further developed through subsequent standards to ATS level.

Pupil Premium

The Chairman raised the issue of equitability, with uneven access by State and Independent schools. Published evidence (eg. Power, 2007) clearly shows that schools with higher proportions of Free School Meals have fewer field trips, and these experiences tend to be narrower and less inspiring. Since the call for evidence closed the government has published its natural Environment White Paper (The Natural Choice). This states that 'we have created a Pupil Premium, intended to raise the attainment of low-income families. This could be used to give fairer access to nature for pupils from deprived backgrounds, for example funding school trips to experience the natural environment'. The Schools Minister, Nick Gibb MP, has repeated this in response to parliamentary questions. We feel that that the use of the Pupil Premium for this purpose is unlikely to happen without very clear and strong guidance from the government.

The FSC recommends that explicit guidance should be given to head teachers and governors, clearly stating that the pupil premium can, and should (when appropriate), be used to support science practicals and field trips.

The demise of science fieldwork for some inner city schools is likely to be exacerbated by a continuing (and possibly accelerating) closure of Local Authority run field centres upon which many secondary schools currently rely for science fieldwork. Recent surveys, including one broadcast by the BBC, show that 33% of such centres think that they are in imminent danger of closing.

Dr Stephen Tilling
Director of Communications
Field Studies Council

30 June 2011

Written evidence submitted by School Travel Forum (Sch Sci 08)

1. Executive Summary

The School Travel Forum (STF) welcomes the Science and Technology Committee's inquiry into practical experiments in school science lessons and science field trips. In this submission the STF would like to highlight the benefits of outdoor education in enhancing a student's engagement with the science curriculum, while also raising concerns about the decline in science field trips in recent years as a result of bureaucratic health and safety burdens on schools as well as inadequate initial teacher training. We would also like to bring to the committee's attention that by working with the School Travel Forum schools can overcome the health and safety barriers and bureaucratic burdens involved in arranging outdoor learning experiences.

In this submission we have used our experience to highlight the following areas:

- The benefits of outdoor education in improving educational attainment.
- The importance of field trips in encouraging pupils to become the scientists of the future.
- The worrying decline science field trips in recent years due to health and safety concerns and bureaucratic procedures which restrict teachers from organising school trips.
- The importance of removing barriers which restrict the effective delivery and implementation of outdoor education and science field trips.
- The need to improve initial teacher training in regard to outdoor education to encourage the use of this teaching method, particularly in the science disciplines.
- The need to introduce an individual entitlement within the National Curriculum to at least one out of school visit a term, including for those from deprived backgrounds via the Pupil Premium.
- The role of the STF in supporting schools undertaking outdoor learning experiences and as an Awarding Body for the Learning Outside the Classroom (LOtC) Quality Badge in supporting schools to deliver effective and safe science field trips.

2. About The School Travel Forum

Since its inception in 2003 the School Travel Forum has won widespread recognition and support for the way it simplifies and provides essential reassurance for leaders looking to organise study, sports and ski trips. The STF, which includes the major companies in the school travel business, has estimated that around 40% of all school visits are organised through our members. Our members are required to adhere to a rigorous Code of Practice and Safety Management Standards and are externally verified each year by a leading

Health and Safety Consultancy. Founded in 2003, the School Travel Forum is a democratic, not for profit organisation of leading school tour operators that promotes good practice and safety in school travel.

Our Objectives include:

- Promoting best practice in educational school travel and support the principles established by the Learning Outside the Classroom Manifesto
- Designing and promoting sector-specific standards that will be periodically reviewed and adapted to reflect changes in education, health and safety legislation and any other relevant influence.
- Ensuring the needs of schools and teachers are understood and adopted into our standards by regularly meeting bodies such as the Learning Outside of the Classroom Council (LOtC), the Department for Education (DfE), the Outdoor Education Advisors Panel (OEAP), Head Teacher Associations and Teacher Unions.
- Ensuring that independent assessment of travel companies offering educational travel in line with the requirements of the LOtC Quality Badge and the STF Code of Practice.
- Providing a forum for members to discuss non-competitive issues of common interest and concern.

3. Background to Outdoor Education

Benefits

The known benefits for pupils of learning outside the classroom are many and varied. They include: improved engagement and attendance; the development of learning and thinking skills; and the strengthening of personal, social and emotional development (e.g. confidence, self-reliance, and management of risk). School trips are becoming increasingly recognised as an important, irreplaceable part of understanding your subject in the real world, as well as being an excellent opportunity for team building and personal development. Evidence also suggests that low attainment can frequently be linked to a lack of engagement in the teaching style, making it vital for schools to examine and use a wider and more flexible range of teaching methods, such as outdoor education, to engage all pupils, particularly those who are at risk of becoming NEET. Ofsted strongly supports the value of outdoor learning experiences as part of a full and rounded education, noting that when well planned and executed, learning outside the classroom “contributed significantly to raising standards and improving pupils’ personal, social and emotional development”[1].

The STF believe that outdoor learning and fieldwork should be a vital element of an imaginative and contemporary science education. Hands-on practical science is known to stimulate and inspire and effectively-planned and well-taught fieldwork is a particularly

[1] Ofsted, *Learning Outside the Classroom: How far should you go?* (October 2008)

powerful approach which helps to improve education standards[2]. 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 science work. Furthermore, and often most importantly, out-of-classroom activity provides an exciting and memorable experience for young people and 77% of teachers feel it to be a more effective teaching method in terms of motivating and enthusing students[3]. In addition, a recent report by the Public Accounts Committee on science education found that a pupils' desire to continue studying depends largely on whether they enjoy and are engaged by the subject[4]. Therefore science fieldwork is a vital way to encourage pupils and students to undertake further science study and encourage them to become the scientists of the future in order to contribute to UK economic growth.

Decline

However despite he benefits, fieldwork provision in science is declining in British schools. More than 96% of GCSE science pupils will not experience a residential field trip, while nearly half of all A-level biology students will do no field work, with the possible exception of half a day's experience near their school[5]. A recent survey by the Association of Teachers and Lecturers (ATL) concluded that children have fewer opportunities to learn outside the classroom than in the past, noting that 17% had not taken their pupils on school trips in the last 12 months.

This is at a time when many studies have indicated a major decline in positive attitudes from students towards science. Young people at secondary school generally see less relevance in science to the real world, find it less inspiring, enjoy less practical work and feel they have less opportunity to use their imagination. Students are 'turning off' science and more work is needed to ensure that students are inspired and to enable the UK to develop a rich source of skilled scientists so vital to the future of the British economy. Outdoor education clearly has a role to play in engaging students and helping them become the scientists of the future.

The former Children, Schools and Families committee conducted an inquiry into Transforming Learning Outside the Classroom in 2010 which warned about the lack of growth in recent years in the number of trips and visits offered by schools[6]. The report also found that pupils from poorer areas are still much less likely to access school trips and argued that there is a danger of children becoming "entombed" in their homes. The committee concluded that:

- Funding to support outdoor learning related initiatives has been derisory.

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[2] National Foundation for Educational Research (2004)
[3] TeacherVoice survey on behalf of the Council for Learning Outside the Classroom (2010)
[4] The Public Accounts Committee, *Educating the Next Generation of Scientists* (2011)
[5] School Science Review, 2003
[6] Children, Schools and Families Select Committee, *Transforming Education Outside the Classroom* (March 2010)

- Teachers' fears over health and safety litigation, making them reluctant to offer trips and visits, have not been effectively addressed.
- Teacher training continues to pay scant attention to giving new teachers the skills and confidence to lead school trips and visits.
- The new 'rarely cover' provisions have led to many schools cutting back on opportunities for pupils and teachers.

4. Health and Safety in Outdoor Education

The STF believes that the safety of children and young people is the most important priority but that there should always be opportunities for young people to experience outdoor learning. However, in our experience, health and safety concerns and other timely bureaucratic procedures are preventing teachers from delivering an enhanced curriculum through outdoor education. Therefore the STF would like to highlight the importance of removing the barriers which restrict the effective delivery and implementation of science fieldwork as well as outdoor education in general. The Government must address these issues if it is to reverse the decline in science fieldwork and raise educational attainment through enhanced outdoor learning experiences.

In recent years the STF has also found that the “rarely covers” guidance has had a significant impact on all the uptake of outdoor learning experiences. As you may be aware, the Government have an agreement with teaching unions which states that teachers must only ‘rarely cover’ for absent colleagues, and in unforeseen circumstances. School trips are considered to be planned absences. Unfortunately there is evidence emerging of outdoor learning activities being cancelled due to the ‘rarely cover’ provisions. We support the view expressed by Anthony Thomas, Chairman of the Council for Learning Outside the Classroom, that young people are becoming “entombed” indoors at least partly due to the “rarely covers” guidance.

In addition, the STF are concerned about the small rise in the number of compensation claims resulting from outdoor activities. It is our understanding that a limited compensation culture has emerged in recent years. However, the public perception of a compensation culture has been greatly inflated through media coverage. The experience of the STF suggests that there is an unnecessary and disproportionate level of risk averseness, particularly among public bodies in the education sector, with which we have most contact. In some cases the approach is to avoid all activities perceived as ‘risky’, to the detriment of children’s experiences of out-of-classroom activity and real-world experience. A recent survey revealed that 46% of teachers placed health and safety concerns, including risk assessment, paperwork and fear of litigation, as one of the most significant barriers to learning outside the classroom, second only to cost[7].

We would also like to bring to your attention that by working with the STF schools can overcome the health and safety barriers and bureaucratic burdens involved in arranging

[7] Opinion Matters survey on behalf of TUI Travel PLC (2010)

school trips. Anecdotal evidence has pointed to a decline in outdoor learning at the school level due to a fear of litigation after accidents and the time commitments for organising trips. Working with the STF schools can overcome these barriers. The STF works to assist schools in identifying external travel providers who deliver good quality teaching and learning experiences and manage risk effectively. This not only reduces the burden on teachers, enabling then to dedicate more time to ensuring a high standard of teaching and learning, but also helps schools to make savings through more effective procedures, ever more important in the current fiscal environment. We welcome the findings of Lord Young's Review and his proposals to simplify the process that schools and other organisations undertake before taking children on outdoor learning experiences. We look forward to working with the Government to implement these proposals and make it significantly easier for children and young people to undertake outdoor learning experiences.

STF members are required to adhere to a rigorous Code of Practice and Safety Management Standards and are externally verified each year by a leading Health and Safety Consultancy. However, only 40% of all school visits are organised through our members so there are hundreds of schools trips taking place every year where there is no guarantee of quality or heath and safety. We would like to see the Government do more to highlight the work that organisations like the STF do in promoting health and safety and challenging providers to raise their game in terms of safety management, the learning opportunities that they provide and helping relieve the burden of bureaucracy in schools.

For teachers, membership of the STF provides an assurance that a provider:

- Meets their need for due diligence
- Takes account of the needs of users
- Operates in a healthy and safe environment
- Has an emphasis on 'learning/skills outcomes

Quality Badge

The STF is one of the Awarding Bodies for the Learning Outside the Classroom (LOtC) Quality Badge which is the self regulation scheme with the widest acceptance. The Quality Badge provides for the first time a national accreditation combining the essential elements of provision – learning and safety – into one easily recognisable and trusted Quality Badge for all types of Learning Outside the Classroom provider organisations. The badge serves an important purpose and helps to promote safety and best practice for outdoor learning providers. Local authorities have previously taken a prominent role in encouraging schools to adopt these standards because they provided a relatively uncomplicated way of ensuring high class provision in outdoor learning as well as meeting health and safety standards. However, the major barrier we have found is that there is a lack of awareness of the badge in schools and we are concerned that this could be further exacerbated by the diminishing role of local authorities in school management. The STF recommends that the

Government works to raise awareness of the Learning Outside the Classroom Council and the Quality Badge in their work providing schools with a list of reputable and recommended travel companies, such as the members of STF. This will enable teachers to source out these administrative burdens in order to enable them to focus on delivering an effective curriculum through outdoor education.

5. Teacher Training and Outdoor Education

Inadequacy of ITT in equipping teachers with the ability to deliver outdoor education

Any reversal in the decline in science field trips will have to be led by teachers. The capacity and enthusiasm to teach science in an outdoor environment will need to be increased by ensuring a high status for outdoor education in Initial Teacher Training (ITT) which equips science teachers with the necessary skills to take their students into the 'outdoor classroom'.

However, the STF believe that ITT is not working effectively enough to help produce sufficient numbers of science teachers with the competence, confidence and commitment to meet the modern day challenges of teaching fieldwork to the next generation of children and young people. A recent report by Kings College London found that the one of key barriers to learning outside the classroom was a lack of teachers' confidence, self-efficacy and access to training[8]. The report recommended greater support for schools to develop their capacity to integrate activities and resources that promote learning outside the classroom as part of the curriculum. In addition, a report by Association for Science Education (ASE) found that the quantity and quality of training and development within ITT for outdoor education is highly variable and is weakened generally by the absence of any minimum training requirement in this regard[9].

Under the current Qualified Teacher Status regime trainee teachers are asked only to recognise opportunities for out of classroom learning, however, even this weak standard is not being reached by some ITT providers. Evidence published in the Association for Science Education's secondary science journal in 2009 shows that some trainee science teachers are getting no training in this area at all. The STF believe the absence of adequate training is due to insufficient importance given to this area.

Minimum Standards for ITT in Outdoor Education

The STF is delighted that the Government has asked Sally Coates to review QTS standards and recommends the review strengthen QTS standards. In order to help in securing the future for science fieldwork we would specifically like to see the Government introduce minimum QTS standards for ITT outdoor education and fieldwork training and development.

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[8] Kings College London, *Beyond Barriers to Learning Outside the Classroom in Natural Environments* (December 2010)
[9] Association for Science Education *Outdoor Science Working Group, Initial Teacher Education and the Outdoor Classroom: Standards for the Future* (2011)

This will help teachers meet the modern day challenges of teaching the science curriculum through high quality outdoor education and encourage the use of this teaching method to help ensure all pupils and students can actively engage with the curriculum to enable them to achieve the highest possible standards.

Specifically, we feel the Government must ensure that trainee teachers: attend, and have an active role, in a school visit as part of their training and have the opportunity to plan and lead a lesson with pupils outside the classroom as part of their training.

6. Entitlement to Outdoor Education in the Curriculum

The STF is of the view that, to ensure that learning outside the classroom is taken seriously by all schools, there should be an individual entitlement within the National Curriculum to at least one out of school visit a term. We would be flexible on the exact wording of the entitlement but would as a starting point suggest that the entitlement contains an opportunity for all young people to experience at least one significant learning outside the classroom visit during their school years. This will allow all children to access the considerable health, personal development and education benefits that outdoor learning can provide.

Pupil Premium

The STF welcomes the Coalition Government's commitment to a Pupil Premium to provide additional funding for more disadvantaged pupils to ensure they benefit from the same opportunities as pupils from richer families. Outdoor education plays a vital role in enhancing the curriculum and raising education attainment, particular for pupils in some of the hardest to reach groups. We specifically endorse Schools Minister Nick Gibb MP's recent Parliamentary Written Answer which states that "school may in future wish to consider using the pupil premium funding to enable such children to benefit from out of school educational activities." We are aware that the Department for Education is exploring options for supporting disadvantaged pupils and we would like to highlight our concerns about the access that pupils from low income families have to school trips and visits; for these children school provision may be the only opportunity they have to experience different environments from their immediate locality. It will be important for the Department of Education to ensure that outdoor learning experiences are included in Government guidance to schools so that every pupil eligible for the Pupil Premium has the option of using it to fund an outdoor experience, such as a science field trip, to enhance their educational experience.

7. The Role of Ofsted in Supporting Outdoor Education

The lack of a statutory requirement for schools to provide outdoor learning and fieldwork (except in geography) means that Ofsted rarely reports on these aspects, apart from national reviews of outdoor provision. Recent national reports by Ofsted have highlighted weaknesses in the level and quality learning outside the classroom, particularly in secondary schools. School inspections have an important role in boosting the profile and importance attributed to teaching and learning approaches. Going forward, the STF would like to see Ofsted inspections include comment on how effectively these are applied outside the classroom as well as within.

Ian Pearson
General Manager
School Travel Forum

10 May 2011

Written evidence submitted by Myscience (Sch Sci 09)

Established in 2004 by the White Rose University Consortium of the Universities of Leeds, Sheffield and York, together with Sheffield Hallam University, Myscience manages the network of Science Learning Centres (the National Centre plus nine Regional Centres) on behalf of the Wellcome Trust and the Department for Education, the National STEM Centre on behalf of the Gatsby Foundation, the LSIS STEM programme and a number of other STEM programmes, including some international activity. Myscience exists to improve young people's engagement with and achievement in science, technology, engineering and mathematics (STEM), by developing and supporting teachers, technicians and others working in STEM education.

1. **The importance of practical work and field trips in science education**

1.1 Practical work and trips are educational experiences which help learners in a number of very important ways. In practical work resides the essence of what science actually *is*; a tried and tested method by which knowledge is discovered and verified. This method is founded on the important principle of obtaining *evidence*. When school pupils experience practical work the significance is that they are actually *doing* science. Through practical work pupils practise the skills of observation and measurement, learning about experimental design, and concepts such as accuracy and validity of data. Practical work also provides compelling corroboration of the ideas and theories within scientific knowledge. Without these first-hand experiences science education would be significantly poorer.

1.2 The 2011 OFSTED publication "Successful Science" provides confirmatory evidence of the value of practical work in science. It reports that the key factors which promoted pupils' engagement, learning and progress in those schools which showed clear progress in science were "more practical science lessons and the development of the skills of scientific enquiry." The same report noted the importance of professional development to support teachers in their use of practical work and other teaching strategies, and singled out teachers' praise for the quality of professional development offered by the Science Learning Centres, which includes a significant number of courses concerned with improving the quality and range of practical work.

1.3 Trips provide a valuable means by which learning in school can be transferred to different settings. They encourage pupils to make connections between knowledge they have gained in their science lessons and the "real" world, as well as linking different areas of the curriculum; both desirable outcomes which can be difficult to achieve within the normal school setting. Trips can also provide an effective way to help pupils see the scope and range of STEM-related jobs, breaking down stereotypes and providing exposure to the wide range of careers which STEM qualifications can lead to. All of these factors promote the relevance of the subject in question, and this in turn contributes to pupil motivation and achievement.

1.4 There is also opportunity for taking teachers to places of scientific interest as part of their professional development, and then these opportunities can enrich the students learning. For example CERN, Geneva works in collaboration with the national network of Science Learning Centres to host such courses. The UK teachers now form the greatest proportion of teachers visiting this facility and evidence has been collected to show that these trips have made a significant impact on student excitement and engagement in physics

1.5 Practical work and field trips are essential ingredients in science education in allowing pupils to experience science in as authentic a way as possible.

2. Possible decline in practical work

2.1 The SCORE report of 2008, which drew on evidence from many stakeholder organisations and individuals, stated that the amount of practical work in schools "has not varied substantially in recent years". For now the more relevant issue around practical work is the quality of the learning experience.

2.2 Four issues are relevant in judgements of quality:

- the purposes of practical work;
- formal assessment of practical skills;
- the quantity of trained physics and chemistry teachers, and technicians;
- use of modern technologies.

2.3 Purposes of practical work

With a few exceptions, the traditional way in which pupils carried out practical work was to perform at a very low cognitive level; "recipe following" during which opportunities for scientific thinking were few. This kind of practical work, which still goes on, often seeks only to confirm ideas or phenomena which have already been taught, and as a consequence the outcomes are generally pre-ordained. Through this subtext of recipe following pupils typically learn that if they do not obtain the expected result then they have got the "wrong answer". This is counterproductive and unscientific, and does not foster positive attitudes to scientific discovery. It is precisely the kind of practical work which research has shown to be ineffective and which recent initiatives such as the "Getting Practical" project aim to improve upon. The purposes of practical work are now broader and more detailed. Science teachers have to be more skilled in eliciting productive learning from practical work than their forebears, simply because much contemporary practical work has more complex learning outcomes than traditional practical experiments. "Getting Practical" is a project led by the Association for Science Education, with the national network of Science Learning Centres, Centre for Science Excellence at Sheffield Hallam University, and CLEAPSS as partners. During the past two years over 2000 teachers from all sectors have engaged with the programme. The programme has encouraged the teachers to consider more carefully the purpose of practical work in science teaching, so that they plan more thoughtfully the practicals they use to develop scientific practical skills, and, perhaps also even more importantly, the areas of scientific concepts and enquiry.

2.4 Formal assessment of practical skills

Assessment of practical skills, particularly at key stage 4, may perversely contribute to narrowing of pupils' experience and prevent opportunities for field trips. A high-stakes assessment culture often leads teachers to focus on only those limited skills that will form the basis of formal assessment. This has resulted in the implementation of practical work that drills pupils learning of such skills, because it facilitates the scoring of maximum marks by as many pupils as possible. This has resulted in practical work which focuses only on those limited skills which will form the basis of assessments, and is designed not for its scientific credentials but because it facilitates the scoring of maximum marks by as many pupils as possible. The outcome is practical work that can be stilted, often uninspiring, and produces extrinsic motivation that disconnects pupils from deep learning and engagement in science by prioritising grades and scores.

2.5 Trained physics and chemistry teachers, and technicians

Another possible cause of a decline in quality is the shortage of trained physics and chemistry teachers. Without specialist teachers and qualified technicians it is inevitable that the quality of practical work will suffer. Professional development through the network of Science Learning Centres has shown to be instrumental in improving non-specialist teachers' knowledge of physics and chemistry and experience in using effective practical work[1]. Teachers on courses aimed at providing non-specialists with skills and knowledge to teach outside their specialism often report that they are far more confident to use practical work as a means to teaching and as a result have seen their pupils becoming more engaged with as well as understanding better the concepts they are trying to get across. The national network of Science Learning Centres provides the UK's most extensive programme of professional development for school and college technicians, with opportunities for accreditation. There is very high demand from technicians for the residential professional development at the National Science Learning Centre, with excellent feedback on the impact this has in schools.

2.6 Use of modern technologies

Technological advances mean that possibilities for practical work, both in its nature and quality, have improved massively. It is now possible to measure, monitor and process experimental data with modern digital sensors. The "cutting edge" of practical work therefore is moving forward at a prodigious rate determined by technological progress, and science teachers will struggle to keep up with it. Many secondary school science departments possess some datalogging equipment, but it is rarely used. There are understandable reasons for this. Teachers might lack the confidence or technical competence to use it. Occasional reliability issues with ICT equipment, and the pressured school environment where there are always many other priorities, mean it is easier to fall back on the old tried and tested methods. It takes time for

[1] Scott, P., Ametller, J., & Edwards, A. (2010) Impact of focussed CPD on teachers' subject and pedagogical knowledge and students' learning. University of Leeds https://www.sciencelearningcentres.org.uk/research-and-impact/LeedsImpactfocussedcpd2010.pdf

teachers to learn how to use the relevant hardware and software, and it also then takes time to develop high quality and meaningful learning experiences with it. Evidence from teachers' views on Science Learning Centre courses shows that professional development on using modern technologies in practical work has impact on pupils' learning.

3. Health and safety concerns play in science lessons and field trips.

3.1 There is a general belief, often perpetuated by the mass media, that pupils nowadays are not allowed to do the sort of things in science lessons which were done "years ago". Frequently health and safety regulations are cited as being behind this situation. This belief is largely unfounded. The truth is that there are *very few* science practical activities which were carried out in the past which are now banned on health and safety grounds. CLEAPSS investigated these erroneous beliefs in 2005. The result was the illuminating report, "Surely that's Banned?" which provides a detailed picture of a situation which, though it may have improved, still exists. Pupils may not, then, be getting experience of some of the more exciting, and usually more hazardous, experiences in science education. This is not because of health and safety *regulations*, but rather because of health and safety *myths*.

3.2 The regulations which apply to school science experiments are to be found under the umbrella of the Health and Safety at Work Law (1974). They include the Control of Substances Hazardous to Health (COSHH) Regulations, Ionising Radiations Regulations, and Personal Protective Equipment (PPE) Regulations. It is not necessary for schools to consult these actual pieces of legislation, as CLEAPSS provides a thorough interpretation of how they impact on the teaching of science. Comprehensive and reliable health and safety information *is* available to science teachers. The perpetuation of myths is likely to arise from organisational deficiencies and the lack of decent initial and in-service health and safety training.

3.3 A growing reluctance to support off-site visits for pupils has been in part influenced by several high-profile fatalities of pupils taking part in school trips. These have often involved outdoor activities and water in particular. As a result, the procedures for trips of *all kinds* have become extremely stringent. The workload involved in running a trip has increased substantially because of the extra administration. There have been cases in which individual teachers have been implicated in pupil deaths. This has caused concern, and a few years ago the NASUWT advised its members against participation in any school trips so that they would not expose themselves to any risk of being sued or prosecuted if a mishap occurred. Although the most serious incidents on school trips have not occurred on science trips, they have been affected nevertheless.

3.4 For a teacher contemplating taking trips, the prospect can be daunting. The good practice guide of 1998 from the then Department of Education and Employment entitled "Health and Safety of pupils on Educational Visits" is full of helpful tips and information, but is 72 pages in total. Although most of this is common sense, it does still provide a useful framework for consistent practice and hence would be difficult to criticise in the light of the pressure to ensure pupils are kept safe on visits. Put simply, the health and safety of pupils on visits has to remain the most important priority, but the bureaucracy around field trips can act as a significant deterrent to teachers.

4 Examination boards recognition of practical experiments and field trips

4.1 Examination boards do recognise the importance of practical work, and specifications include suggestions about possible practical enquiries that pupils could undertake. It is essential that such suggestions are not perceived by teachers to be either compulsory, or restrictive. Individual schools will have different capacities to provide practical work, including equipment, staffing (teachers and technician support), and resources in their local area. Schools must therefore be able to select the practical work that is offered, including having the opportunity to develop their own enquiries. The assessment of practical skills has already been commented on (para 2.4).

4.2 It is difficult to state whether examination boards adequately *recognise* trips. Examination boards do not *suggest* trips, which is not to say they do not endorse them as valuable learning experiences, but for an examination board to make specific recommendations would discriminate against schools in particular geographical or financial circumstances. Thus field trips tend to be invisible in examination board's specifications, contributing to teachers' unwillingness to undertake them.

5. Consequences for science education and career choices

5.1 The quality of science education depends on a large number of factors, and practical work is one factor, albeit an important one. Without a decent practical component, science education would struggle to adequately convey scientific principles, to give learners a realistic and thorough grounding in scientific methods, and to allow practice in practical, equipment handling skills. Consequently it is likely that students would be less well equipped to make informed choices about courses of study post-16, and indeed it is probable fewer would choose to take science subjects because the enjoyment of, and engagement in, the sciences would be diminished by an absence of practical opportunities. Higher education institutions would subsequently find that the smaller number of students opting to study sciences at degree level would be ill equipped to cope with the demands of enquiry based learning. In addition more time would be required to familiarise students with basic laboratory equipment and procedures before moving on to more advanced laboratory-based work which characterises degree level science study. The effect on student performance and achievement would depend inevitably on how one measured these outputs.

6. Recommendations

- Science teachers need more time to be able to research and plan quality learning experiences for pupils. This is particularly the case for the use of new technology, where thorough and effective training needs to accompany the purchase of this expensive equipment. Professional development is important in teachers' provision of the best practical experiences for their pupils.

- Professional development which helps non-specialist teachers improve their competence and confidence in physics and chemistry should continue and be incentivised. Examples are "Physics / Chemistry for non-specialists" and the "Science Additional Specialism Programme" run through the national network of Science Learning Centres; and the Stimulating Physics Network led by the Institute of Physics.

- The importance of well-trained technicians should not be under-estimated. Professional development for technicians should be a focus in developing effective practical work in schools and colleges.

- The profile of health and safety should be clearer so that health and safety myths do not prevail, and training of science teachers should include the wider use of health and safety guidance such as CLEAPSS materials. This in turn will have implications for initial teacher training and professional development.

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Myscience

10 May 2011

Written evidence submitted by the Council for Learning Outside the Classroom (Sch Sci 10)

I enclose evidence on behalf of the Council for Learning Outside the Classroom as to the importance of practical science lessons and field trips for improving individual and school attainment and improving the personal, social and emotional development of young people.

The Council for Learning Outside the Classroom (CLOtC) is an independent, national charity which champions learning outside the classroom (LOtC) and encourages young people to get out and about, because research shows that children learn best through real life experiences. We believe that EVERY child should be given the opportunity to experience life and lessons beyond the classroom walls as a regular part of growing up.

We ensure that more young people have access to these life changing educational experiences by providing support on the ground, facilitating the sharing of best practice and promoting the benefits of LOtC in raising attainment and aspirations, reducing truancy and re-motivating those who are disengaged from their education.

The Council for Learning Outside the Classroom is the awarding body for the LOtC Quality Badge, which recognises providers offering good quality LOtC provision and managing risk effectively. The Council also offers free online guidance to help teachers and youth leaders plan, run and implement effective LOtC experiences.

1.0 <u>Introduction</u>

The Council's response answers the questions most appropriate to its knowledge and expertise, highlighting key points within each section, and following this with supporting evidence.

2.0 <u>How important are practical experiments and field trips in science education?</u>

2.1 <u>Key points</u>:

2.1.1 Regular learning outside the classroom (LOtC), including practical learning and experiments in the school grounds or field trips in the local community and beyond, raises attainment, improves behaviour and re-motivates children who do not respond well in the classroom environment.

2.1.2 LOtC appeals to different learning styles. It makes learning more memorable, enabling pupils to apply what they have learnt inside the classroom to real life situations and giving them hands on skills that equip them for real life and employment.

2.1.3 LOtC is extremely effective in helping to develop scientific skills. LOtC has been demonstrated to move pupils beyond simple knowledge recall to a point where they can apply knowledge, hypothesise and think critically through inspiring real life experiences. It effectively supports learning back inside the classroom.

2.1.4 In order to be most effective, frequent, continuous and progressive opportunities for LOtC should be integrated into the curriculum. It should not be about once a year field trips. The outdoors represents the real world laboratory and quality fieldwork can take place in the school grounds, local community, environmental centres, on residentials and field trips abroad

2.2 <u>Evidence</u>:

2.2.1 **Nundy, S (2001) Raising achievement through the environment: the case for fieldwork and field centres**.
Reinforcement between the affective and cognitive outcomes which resulted in students being able to access higher levels of learning was reported.

Positive impact on long-term memory was identified, due to the memorable nature of the fieldwork setting as well as affective benefits of the residential experience (e.g. improvements in social skills). There was reinforcement between affective and cognitive outcomes which resulted in students being able to access higher levels of learning.

"Residential fieldwork is capable not only of generating positive cognitive and affective learning amongst students, but this may be enhanced significantly compared to that achievable within a classroom environment."

"Fieldwork in new and unfamiliar surroundings creates events and images that significantly enhance long term memory recall, knowledge and understanding."

2.2.2 **Opinion Matters survey on behalf of TUI Travel PLC, 2010.** 99% teachers agreed that children are more animated and engaged when learning outside the classroom

2.2.3 **NFER TeacherVoice survey 2010.** 70% teachers said LOtC is more effective than classroom teaching in engaging different learning styles. 77% teachers said LOtC is more effective than classroom teaching in motivating and enthusing children with regard to learning.

2.2.4 **Malone, K. (2008) Every Experience Matters.** Children engaged in LOtC achieve higher scores in class tests, have greater levels of physical fitness and motor skills development, increased confidence, self esteem, show leadership qualities, are socially competent and more environmentally responsible.

2.2.5 **Ofsted (2008) Learning Outside of the Classroom - How far should you go**? "*Learning outside the classroom contributed significantly to raising standards and improving pupils' personal, social and emotional development and also contributed to the quality and depth of learning. Even when it was not delivered particularly well LOtC still resulted in major learning gains for the young people taking part*."

2.2.6 **Passy, R., Morris, M., and Reed, F. (2010*) Impact of School Gardening on Learning*.** Outcomes from involving pupils in school gardening: *"Greater scientific knowledge and understanding; enhanced literacy and numeracy, including the use of a wider vocabulary and greater oracy skills; increased awareness of the seasons and understanding of food production*."

2.2.7 **Rickinson, M et al (2004) A review of research on outdoor learning**. *"Substantial evidence exists to indicate that fieldwork, properly conceived, adequately planned, well taught and effectively followed up, offers learners opportunities to develop their knowledge and skills in ways that add value to their everyday experiences in the classroom."*

2.2.8 **Cowell, D. & Watkins, R. (2007), Get out of the classroom to study climate change - the 'Spring Bulbs for Schools' project**. The museum outreach programme involved setting up 160 monitoring sites. Students became '*aware of the world around them and the idea that human activity can have noticeable effects, even on a local scale in the school garden*'. '*The project enabled [students] to undertake pattern-seeking and observational activities – aspects of scientific enquiry that are often underdeveloped throughout the science curriculum*'.

3.0 Are practical experiments in science lessons and science field trips in decline? What are the reasons for the decline?

3.1 Key points:

3.1.1 There is evidence of a decline in opportunities for children to learn outside the classroom over recent years.

3.1.2 Increasing pressure on teachers' time and an increasing bureaucratic burden associated with planning LOtC appears to have contributed to this decline.

3.1.3 Cotton wool culture, fear of litigation and concerns over health and safety have also played a part.

3.1.4 The perceived barriers that teachers say prevent them from taking children outside the classroom include funding, health and safety, red tape, lack of confidence, teacher cover issues and concerns over behaviour.

3.2 Evidence:

3.2.1 **Education Select Committee Report, 2009-2010. Transforming Education Outside the Classroom. "***School trips and visits were not seen to have flourished, especially day or residential visits to natural environments. Our evidence suggested that, in subsequent years, pupils' access to school trips and visits had, at best, remained static".*

"A recent survey by the Countryside Alliance showed that, in any year, only around half of 6-15 year-olds go on a trip to the countryside with their school."

"Anthony Thomas, Chair of the Council for Learning Outside the Classroom, having reviewed a series of Ofsted reports, found that even in geography, where fieldwork is a requirement, not all pupils are spending time outside the classroom. He also found that only around 10% of pupils experience learning outside the classroom, broadly defined, as part of their science lessons."

"Fear of litigation remains an important factor in deterring teachers from organising trips and visits. In a separate survey, the Countryside Alliance found that health and safety concerns were still the main barrier to learning outside the classroom for 76% teachers. It was suggested to us that, among school leaders, health and safety is sometimes used as an excuse rather than a reason for not offering trips or practical work."

"Our witnesses stated that there was evidence of learning outside the classroom being cancelled due to the 'rarely cover' provisions—even where bookings had been made well in advance and cover could therefore have been arranged. The Field Studies Council has 17 centres in the UK. It reported that all of them have experienced a significant reduction in bookings and an increase in cancellations, which it attributed to 'rarely cover'."

"*Attendance at training run by the National Science Learning Centre is reported to be down 25% since September, enquiries about specialist courses promoted by the National Centre for Excellence in the Teaching of Mathematics to have dropped by half."*

3.2.2 **Association for Science Education Outdoor Science Working Group. (2011), Outdoor Science.** *"Despite the strengths and advantages that fieldwork can bring to teaching at all ages, there has been a long-term and continuing decline in the provision and condition of outdoor education in science."*

"Some research points to a decline in the provision and condition of fieldwork at primary and secondary levels, and that this is a long term trend in GCSE and A-level science." Sources: Fisher, A. (2001) The demise of fieldwork as an integral part of science education in UK schools and Tilling, S. (2004) Fieldwork in UK secondary schools: influences and provision.

"Issues of health and safety, risk management and cost are the most significant factors reported as limiting fieldwork...Rickinson et al. also highlighted teachers' confidence and expertise in teaching and learning outdoors; requirements of school and university curricula and timetables; difficulties due to shortages of time; resources and support; and more generally the susceptibility of fieldwork to the 'wider changes in the education sector and beyond." Source: Rickinson et al. (2004), A review of research on outdoor learning.

3.2.3 **Power, S. et al. (2009), Out of school learning: variations in provision and participation in secondary schools**. The higher the levels of pupils eligible for Free School Meals, the lower the number of trips and visits offered (at Key Stage 3). The same study also found that the opportunities for LOtC offered by schools serving less affluent areas tended to be narrower in scope than those run by other schools—restricted to the local area, and linked into vocational provision.

"*Despite the potential of out of school learning to open up new learning horizons to disadvantaged students, our research suggests that it is the most disadvantaged pupils who will be offered the least inspiring experiences*".

3.2.4 **Opinion matters survey on behalf of TUI Travel PLC, 2010.** Teachers surveyed identified the top 5 barriers to LOtC as:
57% - Cost
46% - H&S issues (including risk assessments, paperwork, fear of litigation)
41% - Stress of organising
38% - Lack of time
26% - Lack of staff availability to accompany students.

4.0 What part do H&S concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

4.1 Key points:

4.1.1 The role of health and safety concerns in preventing more learning outside the classroom opportunities are well established (see 3.0). Teachers say they are worried about litigation, and hindered by the bureaucracy associated with planning trips.

4.1.2 Many barriers associated with the health and safety requirements are perceived rather than real, as teachers are confused about the legal requirements around risk assessments, ratios etc.

4.1.3 The free online guidance on the Council for Learning Outside the Classroom website www.lotc.org.uk was initially developed for the Department for Education in 2008 (then DCSF) in order to help teachers plan, run and evaluate effective LOtC experiences and overcome the perceived barriers. However, more support is needed in letting teachers know that this free guidance is available to them.

4.1.4 The LOtC Quality Badge is the national accreditation scheme which recognises organisations offering good quality educational provision and managing risk effectively. It was initially developed for the Department for Education (then DCSF) to provide assurance to teachers and reduce paperwork when planning educational visits and is the only industry-led scheme recognised across all ten sectors involved in LOtC provision (including Adventurous Activities, Farming and Countryside, Natural Environment, and Expeditions Overseas). The Outdoor Education Advisers' Panel has endorsed the award and ask that their Local Authority members request that teachers look for the LOtC Quality Badge when planning educational visits. Support is needed in getting the message out to teachers to look for the LOtC Quality Badge when planning educational visits.

4.2 Evidence
See 3.2.

5.0 If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices?

5.1 Key points:

5.1.1 Attainment in science education will be compromised. LOtC has been demonstrated to move pupils beyond simple knowledge recall to a point where they can apply knowledge, hypothesise and think critically through inspiring real life experiences.

5.1.2 Children who are not given access to regular opportunities to learn outside the classroom as part of science education will be disadvantaged. LOtC significantly improves the development of scientific skills and enhances scientific understanding compared to that achievable within the classroom environment.

5.1.3 The skill and attainment levels of young people entering the workforce or higher education will be compromised. LOtC provides young people with real life experiences and help them to develop hands on skills that equip them for real life and employment.

5.1.4 Fewer children will enjoy and engage in scientific education, impacting on the number of quality students entering science and engineering degree level and vocational courses post-16.

5.2 Evidence

5.2.1 **Education Select Committee Report, 2009-2010. Transforming Education Outside the Classroom.** Anthony Thomas, Chair of the Council for Learning Outside the Classroom, having reviewed a series of Ofsted reports, found that even in geography, where fieldwork is a requirement, not all pupils are spending time outside the classroom. He also found that only around 10% pupils experience LOtC, broadly defined, as part of their science lessons. Declining access to laboratory based practical work in science is a related problem. Science can be taught rigorously through LOtC. The relative absence of these opportunities, as well as practical work, undermines the whole basis of science as an experimental learning experience, and leaves pupils ill-equipped to study science at university level.

5.2.2. **Nundy, S (2001) Raising achievement through the environment: the case for fieldwork and field centres.** (See 2.2.1)

5.2.3 **NFER TeacherVoice survey, 2010.** (See 2.2.3)

5.2.4 **Malone, K. (2008) Every Experience Matters.** (See 2.2.4)

5.2.5 **Ofsted (2008) Learning Outside of the Classroom - How far should you go**? (See 2.2.5)

6.0 <u>What changes should be made?</u>

6.1 <u>Key points</u>:

6.1.1 As part of the National Curriculum programme of study for science, provide schools with accompanying guidelines and exemplar materials on how integrating LOtC into the curriculum can be achieved. We have strong evidence which indicates schools require guidelines and information in order to have the freedom to integrate frequent, continuous and progressive LOtC into the curriculum.

6.1.2 Include guidelines for the amount of time to be spent outside the classroom at each key stage (defining what is meant by frequent, continuous and progressive LOtC) within the National Curriculum programme of study for science and/or accompanying guidance notes. These guidelines should highlight the opportunities for LOtC that exist in the school grounds and local community at very low cost as well as opportunities for visits further afield.

6.1.3 Promote the support and guidance available to help science teachers embrace methods of teaching that can bring the curriculum to life. Signpost the free guidance on planning, running and evaluating LOtC on the Council for Learning Outside the Classroom website, www.lotc.org.uk (which the DfE initially helped to support so it already has Departmental endorsement) within the National Curriculum programme of study for science.

6.1.4 LOtC is not a subject area but a method of delivering the curriculum across all subject areas and we hope that the new National Curriculum will include accompanying guidelines highlighting the value of LOtC and how teachers may integrate frequent, continuous and progressive LOtC across the full breadth of the curriculum.

6.1.5 Ensure teachers learn the tools to deliver LOtC through its inclusion in the ITT curriculum. Currently, the ITT requirement is that teachers have to plan an LOtC activity, but they do not have to deliver it. This means that the requirement may be little more than a paper exercise, with no real life experience gained of actually taking children out and about.

6.1.6 Recognise the LOtC Quality Badge as an industry-led, non-statutory scheme to decrease bureaucracy for schools when planning field trips and other educational visits (as recommended in the Lord Young report Common Sense: Common Safety) and promote the scheme to schools within the National Curriculum and accompanying guidance notes.

6.1.7 Reduce bureaucracy for schools when planning school trips in line with Lord Young's recommendations within Common Sense: Common Safety.

6.1.8 The Council for Learning Outside the Classroom has a vital role to play in helping educational establishments incorporate learning outside the classroom across the curriculum and overcome the perceived barriers such as lack of funds, concerns over health and safety and red tape. The Council must be given more support from Government in achieving these aims (including financial support).

6.2 Evidence:

6.2.1 **Opinion matters survey on behalf of Education Travel Group, 2009.** Teachers responded with the following top 5 answers when asked what the Government can do to encourage school trips:
79% - more funding
63% - minimise bureaucracy
43% - offering well accredited organisations and providers
33% - offering more guidance
20% - offering advice and consultancy on school trips.

6.2.2 **Education Select Committee Report, 2009-2010. Transforming Education Outside the Classroom.** *"Fear of litigation remains an important factor in deterring teachers from organising trips and visits. The Countryside Alliance found that health and safety concerns were still the main barrier to learning outside the classroom for 76% teachers. It was suggested to us that, among school leaders, health and safety is sometimes used as an excuse rather than a reason for not offering trips or practical work."*

"Teachers need to be exposed to learning outside the curriculum from early on in their career, and this should not be left to chance. We expect to see a clearer and more consistent presence for learning outside the classroom across initial teacher training and early career and ongoing professional development for teachers."

"Learning outside the classroom is important, and the Department must provide adequate funding to achieve maximum impact...We believe that the allocation of a comparatively small sum would make an enormous difference to learning outside the classroom, and call on the Department to look again at the resources it has provided for the Council for Learning Outside the Classroom and the Quality Badge scheme".

Beth Gardner
Chief Executive
Council for Learning Outside the Classroom

10 May 2011

Supplementary written evidence submitted by the Council for Learning Outside the Classroom (Sch Sci 10a)

Many thanks for inviting me along to give evidence to the Select Committee last week. I hope that the Committee felt that they got what they needed from us!

From our point of view, the Council for Learning Outside the Classroom may have been better placed giving evidence as part of the first session, as that's where most of our experience lies. However, in view of our conversation after the hearing when you invited me to submit additional evidence directly to you, I thought it would be worth getting in touch with you to answer a couple of questions posed by MPs during the first session which were not answered by the panel.

1. Alternatives to the LOtC Quality Badge to recognise learning in schools

Q35 Stephen Metcalfe: Is there a classroom equivalent of that mark, training or qualification?

Dr Tilling: In terms of learning outside the classroom?

Stephen Metcalfe: Yes.

Dr Tilling: There is a classroom link because one of the main criteria is the link and what happens outside with what happens in the classroom.

Colleagues on the first panel would not have been aware that the Council for Learning Outside the Classroom is currently developing an LOtC Mark for schools, which we hope will be launched in September. This is an alternative to the LOtC Quality Badge (which accredits providers of LOtC offering good quality teaching and learning and managing risks effectively, thereby assisting schools to reduce bureaucracy relating to health and safety and fieldwork). The School LOtC Mark will recognise those schools offering frequent, continuous and progressive LOtC experiences as an integrated part of the curriculum, to all their young people. There are three levels: bronze, silver and gold, signifying a school's continuous commitment to the quality of their LOtC (which includes science fieldwork within the school grounds, in the local community and further afield).

2. One central resource to collate all of the information available for teachers

Q36 Stephen Metcalfe: One of the other things that struck certainly me, and I think some of my colleagues, is that there do seem to be an awful lot of schemes and programmes and variety. Do you agree that there is perhaps too much variety and too many different sources of information that make it very difficult to access? Perhaps some of that should be rationalised and we should have one central resource that collates all this information, and then it is more easily accessible so that teachers can access it and make the most of it.

Annette Smith: Are you talking specifically about health and safety in science education?

Q37 Stephen Metcalfe: Yes.

Annette Smith: Steve refers to the local authority role, which was clear up until now. The local authorities, where they still have control, still sign up to CLEAPSS and get regular updates on specific hazards which are pertinent to the classroom in general. That is really a useful service and they can act upon that. Then the schools have responsibility to act upon that. That is fine but it is changing. It is difficult to know where that will end up. Obviously you will be able to speak to those witnesses later on.

Q38 Stephen Metcalfe: Does anyone else want to add anything to that?

This was one of the primary aims of the Council for Learning Outside the Classroom and its website (www.lotc.org.uk). Set up with the financial support of the then DCSF in 2009 to take forward the aims of the LOtC Manifesto, CLOtC works not just to bring organisations and resources together from a science fieldwork perspective, but takes up the challenge even further, broadening out its partnerships to span 10 sectors, comprising:

- Natural environment
- Arts and creativity
- Heritage
- Built environment
- Sacred spaces
- School grounds
- Farming and countryside
- Adventurous activities
- Study, sports and cultural tours
- Overseas expeditions

The CLOtC website was designed as THE place to find information about all learning outside the classroom, ranging from advice and guidance on planning, running and evaluating LOtC to specific resources relating to different sectors. The website continues to develop, and we would be very happy to rise to the challenge of the Select Committee and act as a portal to signpost all teachers and others working with young people to relevant resources and support.

I hope that this additional information proves useful. Good luck with concluding the work, and I look forward to seeing the report. If I can be of any further assistance, please do not hesitate to contact me.

Beth Gardner
Chief Executive
Council for Learning Outside the Classroom

6 July 2011

Written evidence submitted by The Perse School, Cambridge (Sch Sci 11)

School context

1. The Perse School is a selective, independent day school in Cambridge with long established strengths in the sciences. The school benefits from close links with some of the science departments at Cambridge University and with Addenbrookes Hospital.

2. Chemistry, Biology and Physics are compulsory to IGCSE, and examination results are extremely good (75% A* grades at IGCSE in 2011 across the three sciences). The school also has a long tradition of Engineering Technology, and offers AS Technology (instead of GCSE) from Year 10 onwards. All three sciences are popular and growing A-level subjects, and large numbers of students go on to study science, engineering and medicine at university.

3. The sciences are seen as a high status and very successful part of the school's curriculum. As a school, we are convinced that our focus on practical experiments is absolutely fundamental to that success.

Question 1: How important are practical experiments and field trips in science education?

4. Experiments are an **essential** part of the scientific method and are invaluable in helping students to access key concepts. Practical work is central to our philosophy of science teaching. It is in experimentation and analysis of practical results that pupils gain familiarity with scientific tools, and deep understanding of key concepts. Feedback from pupils is that their experience and enjoyment of science experiments are also important reasons for choosing the subjects at A-level.

5. Field trips are very valuable to students especially in biology. At this school we have a joint biology and geography field trip which can contribute to students' GCE marks, together with some small-scale fieldwork in the school grounds themselves. The data collection exercise can lead to useful statistical analysis and give an appreciation of uncertainty in scientific experiments.

Question 2: Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

6. Practical experiments in science lessons are not in decline at this school – quite the contrary. We are fortunate to have been able to continue to recruit new teachers who share our vision for the importance of practical work, including a number who have entered teaching from a background in

post-graduate scientific research. Two other key reasons for the strength of our practical work have been:

(a) Recruiting and retaining some excellent laboratory technicians

(b) Timetabling almost all of our science lessons into subject-specific Biology, Chemistry and Physics laboratories.

7. Science field trips do happen, but perhaps to a lesser extent than in the past. There are no strong reasons why this has declined, but the cost of such trips, the increased time in preparing for them and the shortage of teaching time at A-level all contribute to some extent.

<u>Question 3: What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?</u>

8. There should be very few reasons for practical experiments not to happen in schools. CLEAPSS (whose service and advice is excellent) have a very clear policy of encouraging teachers to realise that very little is banned, but that it is important to ensure that risks are minimised when practicals are carried out.

9. At the Perse School, a risk assessment is required for each experiment. This amount of paperwork appears to be a barrier to some practical work in some schools.

10. From talking to colleagues at other schools, our impression is that a major factor inhibiting practical work (where this happens) is the behaviour of students. In any school the behaviour of individuals or whole groups is an essential part of health & safety considerations, and the safe option at times is not to do a practical.

<u>Question 4: Do examination boards adequately recognise practical experiments and trips?</u>

11. Broadly speaking – yes, they recognise their importance.

12. We do have some reservations about the modes of assessment of practical work. In some cases, examination boards perhaps make it too easy for schools to rehearse their students for practical exams in detail, so that students know in advance what the ‘correct’ outcomes ‘should’ be. We are also aware that assessed practicals can be time-consuming to set up and perform.

13. As a school, we have changed from conventional GCSEs in science to the international IGCSEs (with both CIE and Edexcel exam boards), partly because we believe that IGCSEs offer a more rigorous grounding in scientific concepts and methods than conventional GCSEs. The opportunities for practical work at IGCSE form part of this decision.

We have not commented on questions 5, 6 and 7.

Conclusion

14. We are grateful for the opportunity to contribute to this consultation. We hope that the committee will recognise that practical experiments and fieldwork are fundamental reasons why students gain a passion for science and technology, and are vital ways that students deepen their understanding of the world.

Mr Jeremy Burrows
Head of Science

Dr Chris Pyle
Deputy Head (Curriculum)

10 May 2011

Written evidence submitted by the City and Islington College, London (Sch Sci 12)

1. How important are practical experiments and field trips in science education?

Well thought out practical work is essential in science education for both traditional academic routes as well as more vocational courses.

Regular, rational interaction with the material world through experimentation emphasises the evidence base of science to students. We need to ensure that all citizens have an understanding that scientific theories are based on evidence gleaned through interacting with the physical world and this is best achieved by carrying out this process rather than merely describing it.

Students find good practical work motivating and meaningful, their enjoyment and motivation helps to sustain them in their science studies and encourages them to continue to study science.

Practical work can challenge students' misconceptions, when the physical world behaves in a way that does not fit with a student's view this provides a memorable and undeniable challenge to a misconceived model whilst also reinforces the methods of science.

Related benefits to practical work include using applied mathematics as part of the related calculations, particularly for the physical sciences and this helps address some of the common problems associated with poor mathematics abilities of students.

Practical work provides differentiated activities that stretch students of all abilities. Meaningful practical work can stretch the most able students in a class whilst being accessible to the whole class.

Practical work also helps more vocational students in that it is less threatening than traditional theory based classes and allows the tutor to focus support in the laboratory on the students that most need it.

Open-ended, investigative practical work is important in fostering the enquiring mind and encouraging innovation. Well managed investigations develop the higher level skills in science by demanding that students formulate clear, testable hypotheses; design experiments which test a given hypothesis; make judgments about the uncertainty of experimental data; evaluate the degree to which the results of an experiment are consistent or otherwise with a hypothesis.

A good science education should produce students who:

- are familiar with and can use common laboratory equipment so that they are ready to use such equipment in further study or work
- have experience of carrying out standard procedures and understand the nature and purpose of such procedures so that they can use these procedures in further scientific work and understand that other standard procedures exist

- understand the nature of variables in scientific experiments and can make judgements about the uncertainty of these measurements
- can evaluate the results of scientific data and judge whether or not these support or falsify a theory
- can apply learnt mathematics and understand its relevance

2. Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

Practical work

Practical work is not in decline at City and Islington College, indeed the growth of the vocational science subjects continues to buck the national trend and this was picked up by Prof Wolf when she visited the Centre for applied sciences at the college earlier in the year.

However, there is evidence that there is a decline in practical work in some local schools. The reasons for the decline in practical work are numerous:

- Teachers are concerned about class management and behaviour in a practical class – however it is likely that pupil behaviour will be better if the students are motivated and enjoying their lessons
- Inexperienced teacher are not aware of the range of experimental work that they could use in each topic
- Where there is a high turn-over of younger teachers in a school, knowledge of what equipment is available and what each piece of equipment is and how to use it can be lost from year to year
- Lack of experience laboratory technicians means that preparing practical work is onerous and many teachers do not have the necessary skills even if they could find the time. Good technicians are also important in maintaining and organising equipment so that it is easily accessible and in good working condition. The centre for applied sciences at the college is working closely with the National Skills Academy and the New Engineering Foundation to develop a national framework for technician training to help make this a valued and viable career in the future.
- Cramped and poor designed laboratories can make some practical work difficult
- Lack of investment in good, modern laboratory equipment can discourage teachers from using experiments where the recommended or necessary equipment is not available or not in good condition. Schools and colleges need to explore sharing facilities between themselves and local universities to use resources more efficiently.

Science field trips

Science field trips are threatened by lack of funds, particularly where students and parents do not have the financial resources to pay for such trips and college funds are squeezed. Increased pressure on the curriculum discourages teachers from taking students on field courses which will involve students missing lessons. Teacher workload and the demands of health and safety, child protection and associated paperwork and student-teacher ratios discourage the organisation of field trips.

3. What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

Health and safety concerns do not unreasonably prevent students from performing practical experiments in well run departments. The role of experienced teachers and technician who are kept up to date with good CPD and the availability of advice from CLEAPSS is central to this. However, fears about health and safety may be a factor where staff are unsure or unaware of the guidance and have little experience and no more experienced colleagues to consult.

Field trips have become more onerous for teachers to organise through the various requirements for health and safety and safeguarding even with post-16 students. The required student-teacher ratios and the amount of paperwork and organisation required is likely to curtail the number of trips.

4. Do examination boards adequately recognise practical experiments and trips?

The better examination boards recognise project work which best develops practical science. However, some of the examination boards have removed project work from the assessment of the course. Practical project work needs to be recognised in all A' level science specifications. There is some recognition of trips in some of the specifications but the there is no necessity for a trip in any of the specs.

Practical work is better understood by the vocational exam boards and these offer a greater flexibility in delivery of information to a broader ability range.

5. If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

Student project work is declining where it is no longer an exam board requirement, this means that students do not get such a sense of achievement in their course and are less likely to feel confident about further study of the subject. These students are also less well prepared for investigative work at HE and do not have such a good understanding of scientific research

6. What changes should be made?

Practical work needs to be an essential element of the assessment of all science courses – this will ensure that it is taught well. Larger elements of practical work also allows teacher time to be better focused and mixed ability groups to be more effectively supported. This applies to both traditional A level routes as well as vocational science education.

Schools and colleges should be encouraged to share underutilised resources in local universities and explore the use of local private laboratories. Linking the new Apprenticeship routes with traditional science pathways should allow for a seamless transition from academic and vocational routes to HE or into work.

Science programmes should be appropriately funded from the SFA to ensure continued capital investment in schools and FE colleges. These funds need to be ringfenced in individual institutions to support science areas.

7. Is the experience of schools in England in line with schools in the devolved administrations and other countries?

Practice varies overseas so its hard to compare like with like. Experience at the College is that those students that have had substantial practical work in prior exams do understand the fundamentals of science and are better placed to succeed in their chosen paths.

City and Islington College is a major provider of Science Further Education both though its Sixth Form College and Centre for Applied Sciences

Dr Steven Jones FRSC
Director of the Centre for Applied Sciences
City and Islington College

10 May 2011

Written evidence submitted by the Institution of Chemical Engineers (Sch Sci 13)

Q 3. *What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?*

1. IChemE (the Institution of Chemical Engineers) maintains a keen interest in encouraging more young people to consider a career in chemical engineering.

2. We firmly believe that maintaining student interest in classroom science at a younger age is vital, if they are to pursue an interest in chemical engineering – or indeed any of the other engineering disciplines later in life.

3. With that in mind, we are keen to encourage **more practical science demonstrations** in the classroom and help to **dispel the myth that says 'health and safety prevents classroom demonstrations'**.

4. The enclosed photo shows **Judith Hackitt, a chemical engineer and more importantly Chair of the Health and Safety Executive performing *The Flaming Hands* science demonstration** to an audience of schoolchildren at Bacon's College, London in 2009.

5. Judith Hackitt said: "I fully support IChemE's and Government's initiatives to bring science to life by integrating these sort of classroom demonstrations that make children excited about science...**classroom demos can be spectacular and safe**."

6. Quite simply any time a teacher, parent, journalist or commentator refers to 'health and safety stopping classroom science demonstrations', we'd do well to show them a copy of the enclosed picture.

7. In many cases, these demonstrations can be adapted and used as classroom experiments.

Matt Stalker
Communications Manager
IChemE

10 May 2011

Written evidence submitted by the Royal Society for the Protection of Birds (RSPB) (Sch Sci 14)

Summary

- The RSPB believes that here is diverse evidence of the positive educational impacts of direct, firsthand experiences with real world phenomenon.

- There has also been a decline in learning outdoors in recent years, due to a variety of widely recognised barriers in areas including funding, health and safety, teacher training, and profile in the curriculum.

- For English schools, the Government could take immediate action to address this decline in three specific areas:

  - advice relating to opportunities to target pupil premium funding;

  - underpinning the revised science National Curriculum with regular fieldwork and outdoor learning;

  - enhancing the abilities required for outdoor learning in Qualified Teacher Status standards and newly qualified teacher induction regulations.

1. The RSPB's work with schools and science field trips

The RSPB has over a million members, including 200,000 under the age of 18. As Europe's largest nature conservation organisation, we are also a leading NGO-provider of environmental education. Every year 50,000 pupils learn about biology and ecology on our nature reserves as part of structured, curriculum-linked programmes. These reserves have been independently assessed for the Council for Learning Outside the Classroom's Quality Badge – with the majority being judged excellent or outstanding for their teaching provision as well as health and safety. In addition, 90,000 pupils took part in our most recent *Big Schools Birdwatch* – discovering and counting the birds in their local environment, and analysing their findings back in the classroom.

2. Collaborating for a greener future

In 2010, the RSPB collaborated with The Eden Project and Kew Gardens to deliver a science careers project working with 14-19 year-olds, funded by the Department for Education. The *Green Talent* initiative provided an innovative two-day environmental experience, linked to a three-day work placement in local businesses. Over 150 teenagers took part in groundbreaking sessions at three RSPB nature reserves to learn about such concepts as ecosystem services and triple bottom line accounting, and to consider future job opportunities in a low-carbon economy.

3. **Science and the RSPB**

The RSPB's work is underpinned by sound science and research. We use the best scientific evidence available to guide our conservation policies and practice. Only by basing our work on such evidence can we be confident that our actions will be of benefit to birds and other wildlife. We employ over 120 scientists, whose specialities include species ecology, taxonomy and statistical analysis and modelling. Each year, we have close to 100 papers published in scientific journals. Working with partner organisations, we also offer talented young people the opportunity to work alongside our scientists through the Nuffield Foundation Science Bursaries scheme.

4. **The importance of field trips to education**

There is diverse evidence of the positive educational impacts of direct, firsthand experiences with real world phenomenon. Learning outdoors broadens children's outlook, improves their motivation and personal and inter-personal skills, and creates a sense of place, nature, culture and history that can encourage more active citizenship and political engagement. It provides inspirational experiences, which teachers can use as a springboard for wider curriculum-based work, across core subjects. The RSPB brought together the wide range of research into these benefits in 2010 in the research summary report *Every Child Outdoors*. In 2011, the Association for Science Education's (ASE) Outdoor Science Working Group also published its *Outdoor Science* report which specifically highlighted the educational benefits of teaching and learning science through fieldwork in the natural and built environments.

5. **Changes in participation in science field trips**

The recent ASE report identified that "some research points to a decline in the provision and condition of fieldwork at primary and secondary levels, and that this is a long-term trend in GCSE and A-level science." This reinforces the broader findings and recommendations of the April 2010 Children, Schools and Families Select Committee report into *Transforming Education Outside the Classroom*. Persistent barriers to participation were identified as: "The funding of learning outside the classroom initiatives remains inadequate; teachers' health and safety concerns ... have yet to be assuaged; and teacher training continues to pay scant attention to preparing teachers to lead learning outside the classroom... [I]f it is to be taken seriously by all schools, [learning outside the classroom] needs to be made an entitlement within the National Curriculum."

6. **Reversing the decline**

The RSPB believes that Government action in the following three areas would begin to address these barrier sand reverse the decline in outdoor learning.

a) In England, **pupil premium funding** offers an ideal mechanism for ensuring all underprivileged children have the opportunity to learn outdoors. Schools Minister, Nick Gibb MP, recently stated, "Schools may in future wish to consider using the pupil premium funding to enable such children [eligible for free school meals] to benefit from out of school educational activities." However, the Government should ensure this opinion is very widely known to all schools, so that they may choose to spend this funding to enable outdoor learning in science (and all other subjects).

b) In forthcoming independent research for the RSPB, Ipsos MORI found that science teachers are significantly more likely than any other subject's teachers to consider a 'less rigid and slimmer curriculum' as being encouraging of more teaching outdoors. We therefore believe that this not only supports the Government's current review to slim down the National Curriculum in England, but also that in the **revised science curriculum**, learning across all Key Stages must be underpinned through regular fieldwork investigations and learning outside the classroom.

   In recent years, devolved administrations have made such recognition to schools of the role of outdoor learning in delivering their curricula: in October 2007 the Welsh Assembly Government published *Out of classroom learning: making the most of first hand experiences of the natural environment*; and in April 2010, Learning and Teaching Scotland launched the guidance document *Curriculum for Excellence through Outdoor Learning*.

c) Currently, **Qualified Teacher Status (QTS) standards** in England and Wales require newly qualified teachers to be able "Establish a purposeful and safe learning environment conducive to learning and identify opportunities for learners to learn in out-of-school contexts." The RSPB believes that these standards should be enhanced with regards to outdoor learning beyond being only able to identify these opportunities, to include the ability to plan, undertake and integrate them. In addition, the current Department for Education review of induction regulations for newly qualified teachers should ensure that their first year of teaching requires the demonstration of these abilities.

Tom Fewins
Senior Parliamentary Officer
RSPB

10 May 2011

Written evidence submitted by The British Psychological Society (Sch Sci 15)

Executive Summary

- ‘Doing’ science is an important component of any science course.
- The decline in practical work in psychology has led to an impoverished scientific experience for learners.
- Less practical work in schools has meant that students are less prepared for Higher Education in any science subject, including psychology.
- Less practical work means reduced opportunities to develop skills of group working, practical problem solving and data collection.

How important are practical experiments and field trips in science education?

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 one of the fastest growing science subjects. 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 54,000 students sat the Psychology A level in 2010, significantly more than in Physics (30,976), Chemistry (44,051) and rivalling Biology (57,854). Psychology also attracts a significant number of women to science, as demonstrated by the same figures from the JCQ which show that 40,138 women sat the Psychology A Level in 2010, with the numbers for Physics (6,668), Chemistry (21,057) and Biology (32,635) being in some cases significantly proportionally lower.

How important are practical experiments and field trips in science education?

3. ‘Doing’ science is an essential component of any course in science. It is by collecting data, analysing data and evaluating the quality of the evidence that students gain a realistic understanding of scientific research. Science without practical work is like a cookery course without an oven.

4. In Psychology we regard the methods of science as the cornerstone of any course in the subject. It is essential to know where data and evidence comes from and to further understand what this evidence can tell us and also what it can’t tell us. In higher education laboratory studies sometimes makes up 50% of the course and never less that 30%.

5. Field trips have less value in the study of psychology as our subject matter is all around us. We recognize the value of field trips in other sciences but at a school level we would expect such events to be desirable but non essential extras.

Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

6. The need for schools to provide facilities for the practical work and time for them to take place. Practical work inevitably takes longer to set up and complete than desk-based tasks.

7. The assessment requirements of Examination Boards. The simplest and cheapest assessments are examination based. These assessments have the appearance of being reliable, objective and fair. There have been ongoing concerns about the assessment of practical work through, for example, written coursework because of the difficulty in assuring authorship. The appropriate alternative of assessed practical activities is more difficult and costly to set up. It does, however, have the advantage of assessing the learning outcomes in a valid way. We also argue that it is possible to create fair assessments of practical work in effective and economic ways.

8. In earlier versions of the A Level Psychology programme, students were required to complete 12 pieces of practical work and to keep a laboratory book of their work. They were then interviewed by an external examiner at the end of the course to assess their work and their understanding of it. We would welcome this style of assessment.

9. We recognise the challenges in assessing practical work but we are of the opinion that the activity is so central to the understanding of psychological science that Examination Boards must find ways to deal with this. We are happy to contribute to any discussions and working parties on this topic.

What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

10. There are very few health and safety concerns in the conduct of psychology practical work. However, there are some ethical concerns and the Society provides guidance for its members and for teachers on the conduct of practical activities. We see the consideration of these ethical issues as an important ingredient in the education of the students.

Do examination boards adequately recognise practical experiments and trips?

11. Examination Boards do not adequately recognise the importance of practical work. The main driver here has been the need to create assessments that are easy to mark. This has meant that courses have been adjusted so that they can be easily assessed to the detriment of other aims such as providing a balanced education in the methods of science.

If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievements of pupils and students in Higher Education?

12. Less practical work means that the courses will provide a more impoverished introduction to science and also a less engaging programme of study. Students will be less prepared for scientific courses in higher education and also less likely to apply for them given their relatively dull courses at school.

Kelly Auty
Policy Advisor (Education)
British Psychological Society

10 May 2011

Written evidence submitted by the Association of the British Pharmaceutical Industry (Sch Sci 16)

The Association of the British Pharmaceutical Industry represents more than 70 companies in the United Kingdom producing prescription medicines. Its member companies are involved in all aspects of research, development and manufacture, supplying more than 80 per cent of the medicines prescribed through the National Health Service. The ABPI also represents companies engaged solely in the research and/or development of medicines for human use. In addition, there is general affiliate membership for all other organisations with an interest in the pharmaceutical industry in the United Kingdom.

About the ABPI

The Association of the British Pharmaceutical Industry (ABPI) has 150 members including the large majority of the research-based pharmaceutical companies operating in the UK, both large and small. Our member companies research, develop, manufacture and supply more than 80 per cent of the medicines prescribed through the National Health Service (NHS). In addition, there is affiliated membership for other organisations with an interest in the pharmaceutical industry in the United Kingdom.

The pharmaceutical industry is immensely valuable for the UK and its medicines contribute greatly to improving both the health of the population and the economy as a whole. It is committed to working together with Government and the NHS to deliver value for money from medicines, better patient access to medicines and to ensuring that innovation and research are appropriately and fairly rewarded. Medicines have contributed significantly to increasing overall UK life expectancy and quality of life. The pharmaceutical industry invests more in R&D than any other industry within the UK and one fifth of the most prescribed medicines globally were developed by UK companies. It directly employs around 72,000 people and generated a greater contribution to the UK economy than any other industry sector in 2009 with a trade surplus of almost £7bn.

Key Points

1. An effective science and maths education is essential if young people are to be equipped, not only for the jobs of today, but the industries and jobs of the future.

2. Graduates recruited by UK pharmaceutical companies often have inadequate skills in key areas, including practical skills. Whilst graduate skills are beyond the scope of this Inquiry, development of these skills needs to start in Primary School and be built on throughout a young person's education.

3. We strongly support incorporation of practical hands-on activities within science education. We would like to see minimum proportions of science curriculum time set aside for appropriately challenging practical science activities.

4. The ABPI and our member pharmaceutical companies would like to see more inquiry-led exploration built in to the curriculum and effectively assessed to encourage enthusiasm for practical science.

5. Industry scientists support schools in the delivery of practical science through the STEM Ambassadors programme and in a variety of other ways.

How important are practical experiments in science lessons and science field trips in science education?

6. Research conducted by ABPI in 2008 on the skills new graduates lack, found that 59% of respondents stated that a lack of practical skills was a major concern for them; in total 87% felt it was a concern or major concern.[1] Universities can only build on the skills students have already developed in schools; evidence indicates that there is considerable variation in the quantity and quality of the practical activities that school students' experience.[2]

7. At all levels practical activities, including hands-on experimentation, must be used to aid and extend understanding. Too many practical activities in schools rely on 'recipe following' with insufficient challenge to link the experimental findings to understanding of theoretical principles.

8. Practical 'hands-on' experimentation can also motivate young people to want to study science post-16 and to consider a career in a scientific field. Ofsted, in its 2008 report 'Success in Science', found 'the most stimulating and engaging teaching and the best learning occur when science is brought to life and pupils are given the chance to conduct, record and evaluate their own investigations'. Schools need to raise pupils' aspirations and enjoyment of science and ensure that they nurture the talents of the potential young scientists of the future.

9. Use of virtual tools to support laboratory work and maximise learning should be encouraged. The Pfizer / Royal Society of Chemistry LabSkills project provides pre-work opportunities for students so that the time they spend in the laboratory is more effectively used and their confidence in practical chemistry is enhanced.[3] This resource is being provided free of charge to all UK secondary schools.

10. Based on evidence of the skills new graduates' lack, we strongly support incorporation of practical hands-on activities throughout a young person's science education. We would like to see minimum proportions of science curriculum time set aside for appropriately challenging practical science activities.

11. Pharmaceutical companies, in common with many other science-based industries, encourage staff to become STEM (science, technology, engineering and maths) Ambassadors. These Ambassadors may run practical experiments as part of a STEM club.

12. Opportunities are also provided for enhanced student experience of practical science at centres such as the Life Science Centre in Cumbria.[4] Students can attend day or residential courses at the centre which is run by ex-industry scientists. AstraZeneca has provided state of the art scientific equipment at the centre and provides sponsorship for

[1] Sustaining the Skills Pipeline, ABPI 2008, http://www.abpi.org.uk/our-work/mandi/Documents/2005-STEM-Ed-Skills-TF-Report.pdf
[2] Practical Work in Science, SCORE, December 2008, http://www.score-education.org/media/3668/report.pdf
[3] http://www.labskills.co.uk/rsc.php
[4] www.thelifesciencecentre.org.uk

some of the courses.

What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons?

13. The link between health and safety concerns and practical experimentation in the classroom has been made by many researchers, with some evidence that concerns have been due to teacher lack of confidence.[5] High quality professional development for science teachers and technicians has been available since 2004 through the network of Science Learning Centres but, according to Ofsted, these centres are still under-utilised by many schools.[6] An indication of the importance that the pharmaceutical industry places on continuous professional development for science teachers is given by the fact that pharmaceutical companies are making substantial contributions, through Project Enthuse, to providing financial awards to support teachers attending courses at the National Science Learning Centre.[7]

14. Additional training opportunities have been offered through the Association for Science Education's 'Getting Practical' programme. Getting Practical offers teachers of science at primary, secondary and post 16 level professional development with the aim of improving the effectiveness of learning through practical science lessons. We are disappointed to learn that the Department for Education will no longer provide any funding for this programme beyond July 2011.

15. Other issues have also been found to restrict practical science teaching. For instance the Royal Society of Chemistry found that 'Substantial percentages of schools discounted some of the more exciting, entertaining but pertinent activities because they believe they do not have time to use them or feel them not to be relevant to their work.' This is echoed by the more recent SCORE report where teachers and technicians highlighted the top three barriers to conducting practical work in science as: curriculum content; resources and facilities; time. SCORE also note that teacher demonstrations, whist necessary for some high-risk experiments, are often over-used for reasons that include lack of resources/facilities, health and safety concerns and classroom management issues, as well as time constraints and the requirements of the current curriculum.

16. We recommend that strenuous efforts should be made to overcome all these barriers to enable more young people to have regular opportunities to support their learning through practical hands-on activities.

Do examination boards adequately recognise practical experiments and trips?

17. There is substantial evidence, teachers' and students' voices' as well as independent research evidence, that the assessment regime, as it is currently constructed and

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[5] Surely that's Banned, Royal Society of Chemistry, 2005
http://www.rsc.org/images/Surely_thats_banned_report_tcm18-41416.pdf
Practical Work in Science, SCORE, December 2008
http://www.score-education.org/media/3668/report.pdf
[6] Success in Science, Ofsted, June 2008, http://www.ofsted.gov.uk/Ofsted-home/Publications-andresearch/Browse-all-by/Post-16-learning-and-skills/Read-about-this-new-section/Curriculum/Successin-Science
[7] Information on Enthuse Awards is available at
https://www.sciencelearningcentres.org.uk/centres/national/awards-and-bursaries

conceived, is narrowing the range of activities carried out in schools and reducing the learning on offer to students.[8] SCORE also believe that there is evidence that the current assessment demands are damaging practical science.[9]

18. We do not believe that current assessment of a student's practical skills provides sufficient encouragement to schools to ensure that all students have wide-ranging experience of hands-on practical experimentation, and are able to develop the skills required to make appropriate inferences about their experimental findings.

19. ABPI has provided evidence to the National Curriculum Review where we requested that assessment processes and measures be aligned to the needs of further and higher education and employers; this should include improved assessment of the practical capabilities of students.

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[8] A Review of the Research on Practical Work in School Science, Justin Dillon, King's College London, March 2008, http://www.score-education.org/media/3671/review_of_research.pdf
[9] Practical Work in Science, SCORE, December 2008, http://www.score-education.org/media/3668/report.pdf

bioscience **education**

Descriptive account

Field Study of Plant Diversity: Extending the Whole-Class Knowledge Base through Open-Ended Learning

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Abstract

Students following a pre-Certificate year in biology (the preliminary year of a 4-year BSc programme) learnt about plant diversity through integrated field and classroom studies carried out in an afforested area of north-east England. The students identified, listed and made interpretive drawings of their own choice of the specimens they had collected. This open-ended approach led to the generation of a collective knowledge base, that was much wider than that of the individual students, and that was available to be drawn upon by student groups in their planning of subsequent field project work. The approach contrasts with conventional laboratory teaching of plant diversity, through use of representative specimens, in which all students tend to finish up with an essentially identical and limited range of knowledge and understanding.

Keywords: Field study, Forests, Open-ended learning, Plant diversity

Introduction

The paradigm for learning and teaching in HE is ideally one of student-centred, deep learning rather than teacher-centred delivery of superficially-learnt content. Although espoused, this ideal is not necessarily achieved in practice (Phillips, 2005). For example, in a plant diversity module at an Australian university, Phillips and Baudains (2002) and Phillips *et al.* (2002) found that although the teaching staff aimed to foster in-depth learning this was thwarted by excessive course content, over dependence on formal lecture and laboratory classes, and an examination structure that encouraged rote learning. Furthermore, the introduction of online support, to augment plant material examined in practical classes, was found to encourage cramming for examinations rather than in-depth learning. Within the context of plant diversity and identification, fieldwork is an alternative to conventional lecture and laboratory classes and offers much scope for student-centred learning.

In the UK there is evidence for a decline in field work amongst bioscience HE students, perhaps because of financial reasons (Smith, 2004).But there is a general belief amongst educators involved in field work that it is a good thing, although Maskall and Stokes (2008) point to a lack of firm research-based evidence that field work is more effective than other learning modes. A controlled experimental study by Taraban *et al.* (2004) did, however, show that students learnt plant identification more effectively through living plants in greenhouse and field environments than through online learning. This result validated the pragmatic approach to weed identification taken by US universities where a survey by Lindquist *et al.* (1989) found that learning to identify weeds included field work in 19 out of 20 universities. Indeed, the learning continuum that encompasses lectures, laboratory classes and field work, reasonably includes the fostering of learning about plants and animals through students' development of a personal and individual interest in the countryside and natural history (Westgarth-Smith, 2003), an achievement that is likely to lead to in-depth and life-long learning.

The present authors' experience of teaching plant diversity includes the conventional approach of laboratory classes in which a limited range of specimens is provided for students to examine, interpret, draw and label. The specimens are living, pressed or pickled and chosen to represent a range of taxonomic groups. For example first-year (Level 4: Certificate Level) students in Biological Sciences, University of Hull, take a module entitled *Plant and Animal Diversity* which includes a laboratory class in which they interpret, and make annotated drawings of five taxonomically-diverse microscopic algae provided in living cultures, and a class in which living specimens of four liverworts and mosses are photographed, drawn and used to produce an illustrated group report on bryophyte diversity. The students potentially acquire in-depth knowledge about the specimens provided but the range of examples which they encounter is very limited. An alternative approach is open-ended learning, where the learning outcomes do not require that all students achieve an identical knowledge base, and there is neither a closed set nor a fixed number of examples for study. This approach is possible using web-based collections of electronic images of plants; we argue however that it is a richer learning experience if students encounter a wide range of real plants growing in a field environment. The present contribution describes how students used open-ended learning to study plant diversity in an afforested landscape in north-east England.

The students were undertaking a pre-Certificate (pre-Level 4) year in biology at the University of Hull. This course, which has run since 2007–2008 when the University took pre-Certificate Level teaching in-house from FE partner colleges, is approximately equivalent to A-Levels. The students have diverse entry qualifications; some have non-science A-Levels, some have done badly in science A-Levels, some are mature students returning to education without formal qualifications, and some are overseas students. The pre-Certificate year leads to three further years (Levels 4–6) of a BSc programme at either the University's Hull campus or its Scarborough campus. Some students progress to BSc programmes that are specifically environmentally related while others progress to read Biology, Human Biology, or Biomedical Science. One sixth (20 credits) of the pre-Certificate year is made up of a module entitled *Biological Diversity*. The aims of this module include the students acquiring knowledge and understanding of the diversity of plants and animals through participation in biological field work. The module is designed so that it is self contained, for those students who do no further study of biological diversity, while not pre-empting the content of the Level 4 diversity modules that are taken later by the other students.

Students participating in the pre-Certificate *Biological Diversity* module undertake six days of field work. In 2008–2009 three of these days were used for study of inter-tidal organisms, principally animals, at Scarborough, North Yorkshire; that is two days comprising a morning observing and collecting animals from either a rocky or a sandy shore followed by an afternoon in a laboratory on the University's Scarborough campus interpreting and drawing these animals. On the third field day there were group projects on inter-tidal organisms, designed by students in consultation with tutors, which drew upon the experience gained during the initial two days of field work. The further three days of field work were devoted to the study of plant diversity at Dalby Forest in North Yorkshire; two days spent observing plants and a third day occupied by a group project.

Study of plant diversity at Dalby Forest

Dalby Forest is an extensive (about 32 km^2) afforested area. It is situated on the slopes and valleys of the Tabular Hills in the North York Moors National Park, about 7 km north-east of Pickering, and has a mixed geology of Jurassic deposits which include grits and oolitic limestone (Staniforth, 1993; Atherden and Simmons, 1996). The Forestry Commission has undertaken large scale planting of coniferous trees from 1921 onwards (Perry, 1983; Osborne, 2007). The forest was initially planted to provide a strategic reserve of timber; latterly its remit has been extended beyond timber production to include enhancement of the visual quality of landscape, recreation, education and wildlife conservation. Forest management has included thinning, clear felling, replanting with a diversity of trees including broad-leaved species, and allowing natural tree regeneration. Also within the forest boundary are streams with distinct corridors of riparian vegetation, forest roads with well-vegetated verges, areas of beech woodland on limestone, and fragments of upland heath that predate the extensive planting of conifers. There is, therefore, much botanical diversity within the forest.

Field work at Dalby forest was carried out in March–April 2009. The first day was given over to trees and shrubs and consisted of a morning during which groups of 4–8 students walked in the forest accompanied by a tutor. The route taken was about 4 km, along paths and forest roads that are way-marked for recreational walking by the Forestry Commission; this provided easy access to a wide range of vegetation types, including first and second generation coniferous forest of various ages, thinned and clear-felled areas of forest, beech woodland, and streamside and roadside corridors. The students were asked to distinguish between different species of trees and shrubs, without at that stage necessarily naming them, although it was apparent that some of the students already knew some of the trees and tutors were able to give help with identification of others. Each group was encouraged sparingly to collect, from each encountered tree species, a sample of foliage, or of the (then) leafless twigs of deciduous trees for later identification and drawing. The students were also encouraged to take a wider view of the forest, beyond the individual trees, by looking for evidence of how the forest has been managed. The students spent the afternoon in a classroom, located within the forest at Low Dalby, which schools and colleges may hire from the Forestry Commission. They were encouraged to help one another by working in loose, self-selected groups and were asked to identify the samples that they had collected and to each collate two lists; one of coniferous trees, the other of broad-leaved trees and shrubs. The lists were to include Latin and English names plus brief notes, based on the students' own field observations, about the broad habitat occupied by each example: e.g. mature conifer plantation; clear-felled plantation; beech woodland; roadside; streamside. To help with identification, the students were each given a ×10 hand lens, and copies were provided of an illustrated key to trees in the form of a glossy folding card, published by the Field Studies Council (Oldham and Roberts, 2003). This is one of a range of illustrated habitat-based cards, designed to assist beginners to identify plants and animals; we have found that undergraduate students enjoy using them and that they can lead to use of more conventional text-based floras (Goulder and Scott, 2006). Further help with identification was provided by copies of an illustrated guide to trees (Mitchell, 1978) and by the tutors. The students were also asked individually to draw, label and annotate at least three examples of the samples of trees and shrubs that they had collected. At the end of the day the students' work was taken in for marking (10% of the module). Also in the afternoon, there was a 30 minute talk, given by a Forestry Commission Wildlife Officer, which was an introduction to the history and management of the forest and to how future developments are planned.

The second day of field work followed a similar pattern but the focus was on bryophytes and vascular ground flora. Specimens were once more sparingly collected in the morning while in the afternoon the plants were identified, using copies of an illustrated guide to the mosses and liverworts that are commonly found in woodlands (Perry, 1992), and again using the relevant Field Studies Council illustrated folding cards; i.e. the cards for woodland plants (Gulliver *et al.*, 1998), heathland plants (Jones, 1998) and ferns (Merryweather and Roberts, 2005). Copies of a guide to wild flowers (Rose, 2006) and the tutors were available to provide further help. Students were asked to make two lists, of bryophytes and ground flora, with Latin and English names plus habitat notes, and were asked to make labelled and annotated drawings of at least three of their plant specimens. The work was again taken in at the end of the day for marking.

Also in the afternoon, the students, in consultation with tutors, planned group project work to be carried out during their third day of field work in the forest.

Table 1 *Trees and shrubs identified and listed by pre-Certificate Level students at Dalby Forest, March 2009*

Coniferous trees	Broad-leaved trees and shrubs
Abies grandis (Grand fir) (16)*	*Acer pseudoplatanus* (Sycamore) (8)
Abies procera (Noble fir)† (13)	*Aesculus hippocastanum* (Horse chestnut) (35)
Abies species (Firs) (5)	*Alnus glutinosa* (Common alder) (18)
Chamaecyparis species (False cypresses) (13)	*Alnus rubra* (Red alder)† (5)
Cupressus species (Cypresses)† (1)	*Betula pendula* (Silver birch) (42)
Larix species (Larches) (35)	*Betula pubescens* (Downy birch) (9)
Picea abies (Norway spruce) (26)	*Corylus avellana* (Hazel) (38)
Picea omorika (Serbian spruce)† (2)	*Crataegus monogyna* (Hawthorn) (8)
Picea sitchensis (Sitka spruce) (24)	*Fagus sylvatica* (Beech) (45)
Picea species (Spruces) (4)	*Fraxinus excelsior* (Ash) (39)
Pinus contorta (Lodgepole pine) (8)	*Ilex aquifolium* (Holly) (45)
Pinus nigra (Corsican pine) (12)	*Lonicera periclymenum* (Honeysuckle) (4)
Pinus sylvestris (Scots pine) (29)	*Malus sylvestris* (Crab apple) (1)
Pinus species (Pines) (2)	*Populus tremula* (Aspen)† (3)
Pseudotsuga menziesii (Douglas fir) (14)	*Populus* species (Poplars) (1)
Taxus baccata (Yew) (4)	*Prunus avium* (Wild cherry) (5)
Thuja plicata (Western red cedar) (16)	*Prunus serrulata* (Japanese cherry) (6)
Tsuga heterophylla (Western hemlock) (26)	*Quercus cerris* (Turkey oak)† (1)
	Quercus ilex (Holm oak)† (1)
n of taxa = 18	*Quercus petraea* (Sessile oak) (2)
	Quercus robur (Pedunculate oak) (7)
	Quercus species (Oaks) (5)
	Rubus fruticosus agg. (Brambles) (3)
	Salix caprea (Goat willow) (13)
	Salix species (Willows) (6)
	Sambucus nigra (Elder) (26)
	Sorbus aucuparia (Rowan) (6)
	n of taxa = 27

**n of records from 52 students are shown in brackets.*

†Student identifications about which the authors have reservations: particularly, specimens identified as Abies procera were probably A. concolor, white fir; those identified as Alnus rubra were probably A. glutinosa; that identified as Cupressus sp. was probably ×Cupressocyparis leylandii, Leyland cypress.

It became apparent to the authors that the students, during the course of their work in forest and classroom, were engaging with a wide range of plants from a diversity of systematic groups; i.e. liverworts, mosses, ferns, conifers, and angiosperm trees, shrubs and herbs. In support of this observation quantitative information was obtained from the notebooks that had been handed in at the end of the day spent studying trees and shrubs. The 52 students who attended had between them collected, identified and listed 45 taxa; 18 coniferous trees and 27 broad-leaved (angiosperm) trees and shrubs (Table 1). The lists of trees and shrubs varied considerably between students in both composition and number of taxa. Among conifers, *Larix* spp., larch, was most frequently listed (35 students) while four taxa were listed by between 21–30 students, six by between 11–20 students, and seven by 1–10 students. Among broad-leaved trees and shrubs, *Ilex aquifolium*, holly, and *Fagus sylvatica*, beech, were both listed by 45 students; *Betula pendula*, silver birch, was listed 42 times, *Fraxinus excelsior*, ash, 39 times, *Corylus avellana*, hazel, 38 times and *Aesculus hippocastanum*, horse chestnut, 35 times. *Sambucus* *nigra*, elder, was listed by 26 students while two taxa were listed between 11–20 times and 18 taxa between 1–10 times. The number of taxa listed per student ranged from six to 22 (mean = 12.2, *sd* = 3.9, *n* = 52). The individual students tended to include more broad-leaved taxa (range 2–13, mean = 7.4, *sd* = 2.5, *n* = 52) than coniferous taxa (range 1–11, mean = 4.8, *sd* = 2.3, *n* = 52).

Table 2 *Trees and shrubs identified and drawn by pre-Certificate Level students at Dalby Forest, March 2009*

Coniferous trees	Broad-leaved trees and shrubs
Abies grandis (Grand fir) (6)*	*Aesculus hippocastanum* (Horse chestnut) (5)
Abies procera (Noble fir)† (9)	*Alnus glutinosa* (Common alder) (6)
Abies species (Firs) (2)	*Alnus rubra* (Red alder)† (2)
Chamaecyparis species (False cypresses) (8)	*Betula pendula* (Silver birch) (1)
Larix species (Larches) (2)	*Corylus avellana* (Hazel) (7)
Picea abies (Norway spruce) (11)	*Fagus sylvatica* (Beech) (4)
Picea sitchensis (Sitka spruce) (12)	*Fraxinus excelsior* (Ash) (5)
Pinus nigra (Corsican pine) (7)	*Ilex aquifolium* (Holly) (28)
Pinus sylvestris (Scots pine) (5)	*Lonicera periclymenum* (Honeysuckle) (1)
Taxus baccata (Yew) (3)	*Populus tremula* (Aspen)† (1)
Thuja plicata (Western red cedar) (10)	*Quercus robur* (Pedunculate oak) (3)
Tsuga heterophylla (Western hemlock) (12)	*Salix caprea* (Goat willow) (5)
n of taxa drawn = 12	n of taxa drawn = 12

**n of drawings made by 52 students are shown in brackets. †Student identifications about which the authors have reservations.*

Individual students chose examples of their specimens of trees and shrubs, usually three, to make pencil drawings. These they labelled and annotated with help from the tree guides provided (Mitchell, 1978; Oldham and Roberts, 2003), from each other, and from the tutors. This gave them the opportunity to develop an in-depth knowledge of the examples chosen. Between them the 52 students made 155 drawings; 87 of coniferous trees and 68 of broad-leaved trees and shrubs. Twenty four taxa, out of the 45 taxa collected, were chosen (Table 2); these comprised 12 coniferous trees and 12 broad-leaved trees and shrubs. The most frequently selected coniferous trees were *Picea sitchensis*, Sitka spruce, and *Tsuga heterophylla*, western hemlock, both drawn by 12 students, followed by *Picea abies*, Norway spruce, drawn by 11 students, and *Thuja plicata*, western red cedar, drawn by 10. Among broad-leaved trees and shrubs, *I. aquifolium* was drawn by 28 students while the next popular, *C. avellana*, was drawn by only seven students.

Discussion

The use of open-ended field-based learning for the study of plant diversity at Dalby Forest demonstrated that the approach has advantages over conventional laboratory-based teaching.

- The approach led to a much wider whole-class base of knowledge and understanding. In the case of coniferous trees and broad-leaved trees and shrubs, for example, the class as a whole identified and listed 45 different taxa (Table 1) of which 24 were chosen for drawing, labelling and annotation (Table 2). This outcome contrasts with the conventional approach where many fewer specimens are generally provided and all students finish with an essentially identical and limited range of knowledge and experience.
- Because the whole-class knowledge base became much wider than that of the individual students, this meant that when student groups planned projects, to do

on their third day in the forest, they had a wide collective knowledge base to draw upon and share. Thus, for example, they were able to undertake projects that contrasted tree species and ground flora along stream corridors with those along verges of forest roads, and that related abundance and diversity of ground flora to shading by trees and to trampling by walkers.

- The students' interest was held because they were free to choose to draw those examples that particularly interested them. Student feedback on the seashore and forest experience included:

> *"This helped me as I could choose animals and plants that interested me."*

Thus, while some of the trees and shrubs that were most frequently encountered in the forest were well represented amongst the students' drawings (e.g. *P. sitchensis*, *T. heterophylla*) others that were less abundant, but had immediately striking characteristics, or perhaps personal associations, were also popular choices (e.g. *T. plicata* for its pineapple smell, *P. abies* with Christmas associations, *I. aquifolium* for its shiny spiny evergreen leaves, and *C. avellana* for its catkins).

- The plants were encountered in their field context rather than as isolated laboratory specimens; this gave the opportunity for appreciation of plant diversity, form and function within an ecological context.
- The use of an integrated field and classroom approach was appreciated, and, after a years' reflection, attracted some profound comment from a student who took the module in 2007–2008:

> *"I think it's important to consider that the field studies in 58007 Biological Diversity always included some related laboratory/indoor work – identifying & drawing specimens collected – and so it is hard to cleanly tease away the field work from the lab work. In terms of enjoyment, this is definitely preferable – to be able to view the organisms in their environment first hand and then apply that to what we see in the lab."*

- The use of integrated field and classroom days also ensured that shelter was available and that the distribution of time between field and classroom could be varied according to weather conditions. Learning and teaching continued even on snowy days; provoking student feedback:

> *"I really enjoyed all field trips no matter the weather".*

Unsurprisingly there were some potential drawbacks to the open-ended field based learning approach used at Dalby Forest which need to be set against the advantages.

- The quantity of work done varied substantially between students. For example, the number of tree and shrub taxa identified and listed ranged from six to 22 per student. There is the likelihood that less motivated students addressed fewer plants than they would have in a formal laboratory practical class; although other students evidently took the opportunity to address more than would have been possible in a conventional class.
- It is likely that some of the plants were misidentified. This would not happen in a conventional class in which defined specimens are provided. A degree of misidentification of plants collected from the field is not surprising. Scott and Hallam (2002) found that nearly 6% of diverse UK plant specimens were wrongly identified at species level by professional field botanists; it is certainly to be expected that students will make mistakes. Furthermore, tree identification can be especially problematical around Low Dalby because it is a former Forestry Commission village; forestry employees tend to have a personal interest in trees and are liable to plant examples of diverse exotic taxa. The purposes of the work at Dalby Forest did not,

however, include making reliable records of plant distribution and the view taken is that it was largely adequate for students to name plants to genus and be aware of some of the distinguishing features of the relevant genera. The information in Tables 1 and 2 was taken from the students' notebooks; identifications about which the authors have specific reservations are indicated in the tables.

- The approach demanded substantial resources. There was the cost of transporting students by coach from the Hull campus to Dalby Forest, and of the hire of the classroom from the Forestry Commission. Also, because of the limited capacity of the classroom and the large class size, it was necessary to duplicate the first two days of field work. A low student to tutor ratio is preferable for field work; the ratio was kept down to 8:1 or less by using both experienced technical staff and academic staff as tutors. To be set against these demands, however, is that academic staff and demonstrators were not needed to run conventional laboratory classes, space was not taken up in on-campus laboratories that were running at near full capacity, preparation room staff did not have to set up and clear the laboratories, and there was no need to grow and/or collect plants in advance of laboratory classes.
- Student feedback suggested that long coach journeys (about 1.5 hours each way) led to a lot of non-productive time:

> *"Field study is in a way more interesting but it's far easier to learn in the lab when you have everything in front of you and there aren't hours wasted in the day."*

The authors' subjective perception is that the advantages to the students of open-ended learning about plant diversity in the field environment outweighed the drawbacks. This conclusion, however, is based on our observations and pedagogic experience rather than on the research-based evidence sought by Maskall and Stokes (2008). If controlled experiments are to be used to explore the learning process in HE there are likely to be disadvantaged control groups. In the experiments done by Taraban *et al.* (2004), for example, students were randomly assigned to groups that learnt plant identification using living material or online resources but both groups were assessed using living material; a procedure that potentially disadvantaged the online-learning group. Such disadvantaging is apparently shown by a study in a US university (Brickman *et al.*, 2009) in which non-science students were allocated, without choice of learning mode, to groups that learnt biology laboratory skills either by following a traditional curriculum or by enquiry-based learning. The latter group did marginally better in gaining laboratory skills but enjoyed the learning experience less than the traditionally taught group. There are ethical issues here related to the need for informed consent, especially in the context of an HE structure, such as in the University of Hull, where performance in all modules contributes to either progression or degree classification. These issues need to be reconciled with the need for objective, experiment-based, evaluation of the benefits of fieldwork.

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The Value of Fieldwork in Life and Environmental Sciences in the Context of Higher Education: A Case Study in Learning About Biodiversity

Graham W. Scott · Raymond Goulder · Phillip Wheeler · Lisa J. Scott · Michelle L. Tobin · Sara Marsham

Abstract Fieldwork is assumed by most practitioners to be an important if not essential component of a degree level education in the environmental sciences. However, there is strong evidence that as a result of a wide range of pressures (academic, financial and societal) fieldwork is in decline in the UK and elsewhere. In this paper we discuss the value of fieldwork in a higher education context and present the results of a case study which illustrates its value to student learning and the wider student experience. We used qualitative and quantitative methods to compare the impact of two learning tasks upon the affective and cognitive domains of students. We designed two tasks. One task that included fieldwork, and required students to collect organisms from the field and make labelled drawings of them, and one task that omitted the fieldwork and simply required drawing of specimens that the students had not collected. We evaluated the students' experience through structured and semi-structured questionnaires and written exercises. Students did not perceive the two tasks as being equivalent to one another. They reported that they enjoy fieldwork and value it (in the contexts of their learning at university, life-long learning, and in relation to their career aspirations) and felt that they learn more effectively in the field. Our students were better able to construct a taxonomic list of organisms that they had collected themselves, better able to recall the structural detail of these organisms and were better able to recall the detail of an ecological sampling methodology that they had personally carried out in the field rather than one that a tutor had described to them in a classroom setting. Our case study supports the growing body of evidence that fieldwork is an important way of enhancing undergraduate learning and highlights some key areas for future research.

Keywords Fieldwork · Field studies · Field based learning · Biodiversity · Environmental science · Ecology

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Introduction

Fieldwork is assumed by most practitioners to be an important, and often essential, component of undergraduate programmes in the Environmental Sciences (Biology, Ecology, Geography, Geology etc.) (e.g. Maskall and Stokes 2008). Enthusiastic tutors who deliver field study are often unequivocal in the view that fieldwork is a good thing. This is usually on the basis of their perception of the benefits of field trips, which are summarised in the UK HE (Higher Education) Biology context by Smith (2004) as:

- field-trips are a rewarding and satisfying experience for both students and tutors;
- they improve recruitment to courses;
- they enhance student retention;
- students benefit academically from intensive blocks of focused teaching;
- they enable students to gain key practical/subject skills and transferable skills.

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Our extensive personal experience as student participants in organised field studies and as providers of both one day and residential field trips, together with similar experiences described by others (e.g. Herrick 2010), leads us to agree with these views.

Furthermore, McGuiness and Simm (2005) consider that "fieldwork plays an essential role in delivering real-world relevant content" and Herrick (2010) suggests that because fieldwork provides students with the opportunity to engage with, and adapt to, uncertainty it can enable transformative learning. Fieldwork is often also viewed as enabling the kind of deeper learning which can come from direct experience (Boyle et al. 2007).

However, in the UK at least, fieldwork at both the HE and pre-HE level is under threat (Barker et al. 2002; Smith 2004; Tilling 2004). Across the wider education sector there is strong evidence that in recent years factors such as rising transport and accommodation costs (e.g. Smith 2004; Tilling 2004), changes in education priorities and overcrowded curricula (e.g. Rickinson et al. 2004), reluctance on the part of some students to be away from home (usually associated with loss of income from part-time work or to the risk of losing a part-time job; Smith 2004) and tutor concerns over health and safety regulation (e.g. Rickinson et al. 2004) have all contributed to a decline in the amount of field-based teaching that is available (Rickinson et al. 2004; Smith 2004). Perhaps of more concern is the perception of some in HE (and in the Biological Sciences in particular) that a significant proportion of those members of staff who have championed fieldwork are at or near retirement, and that they are rarely replaced with academics who have the inclination, experience and/or skill-set to continue the activity (Davenport 1998; Smith 2004). Lack of experience and key skills, which may be real or perceived, associated with lack of teacher confidence, have also been implicated in the decline of field-studies at school level (Tal and Morag 2009; Nundy et al. 2009). As part of their training, teachers in the UK are provided with opportunities to develop the skills that they require as field teachers; but there is evidence that the effectiveness of this training varies between training institutions and is not adequately reinforced during school placements (Kendall et al. 2006). In HE we are not aware of specific training in field teaching for academics; skills are initially developed through observation of one's own tutors and colleagues, and over time through reflection upon experience.

Perhaps as a consequence of this, there has in recent years been an increase in the number of private individuals and organisations that provide support to teachers/lecturers through taking responsibility for elements of outdoor learning. In the UK examples include *Forest Schools* (www.forestschools.com), The Field Studies Council (www.field-studies-council.org) and PGL (www.PGL.org) who offer environmental learning as part of a residential experience which is often combined with adventure activities. At the HE level organisations such as Operation Wallacea (www.opwall.com) provide students with vacation time adventure fieldwork, often as part of a programme of scientific research. However, whilst support of this kind may fill some of the needs of the learner it is unlikely to enhance the confidence and skills of their teachers and of course is dependent upon the ability of the institution and/or students or parents to cover the costs incurred. We feel therefore that such external provision can only ever be a welcome addition to school/college/university based field-studies and not a replacement for them.

Should the decline in fieldwork be a concern? We believe that it should for two key reasons.

Firstly, environmental education generally (and we would argue field work related to biodiversity assessment and ecosystem health specifically) has been brought to the fore by The 1972 Stockholm Conference, The 1992 Rio Summit and the 2008 Bonn Conference. Chapter 36 of Agenda 21 (an outcome of the 1992 Rio Summit) clearly states that "education is critical for promoting sustainable development" (UNCED 1992). In the UK, central government has made the link between biological education, societal environmental literacy and environmental policy implementation, recognising that the incorporation of the attitudes and opinions of the public into formal policy decisions will make their implementation more likely (House of Lords' Select Committee on Science and Technology 2000). In 2008 the same Select Committee put forward proposals to reverse what it saw as an "astonishing lack of awareness in Government, both of the importance of systematic biology and of the current state of decline in areas of systematic biology" (House of Lords' Select Committee on Science and Technology 2008). In the 2008 report it is stated that "biology in schools strongly emphasises human biology while concerns over safety issues have led to a reduction in field study trips" and that "it is critically important that school children of all ages, starting with those in primary school, should be taught about the natural world and given opportunities to enjoy it first hand". The report concludes that "Field study trips and other practical exercises, which have served to introduce generations of children to the diversity of living organisms, should be encouraged as a means of engaging and stimulating young people (as future volunteers) to become involved in biological recording". In our view this argument must be carried forward beyond school level education, into the HE sector and onwards through lifelong learning.

Secondly, if the perceptions of practitioners are correct and fieldwork and field-based learning in the wider sense do indeed have added value as a mode of learning, then they have obvious educational value *per se*. This is an argument which is at times difficult to support. In HE there is an acknowledged lack of firm research-based evidence to support the claim that "fieldwork is good", or more importantly that it is more effective than other modes of learning (Maskall and Stokes 2008). It is also recognised that comparative studies of fieldwork and other learning modes "whilst important, are rare and difficult to carry out" (Dillon et al. 2006). Encouragingly, however, Rickinson et al. (2004) in their review of field-based teaching in the UK during the 1990s and 2000s report that there has been an increase in empirical research in the area, "often involving action research and theoretical development". For example Taraban et al. (2004) demonstrated by controlled experimental study that students learned plant identification more effectively through engagement with living plants in a field study context (glass-house and campus environments) than they did through online learning. Goulder and Scott (2009) showed that groups of students, allowed to manage aspects of their own learning in a field-based situation, engaged with a wider range of organisms (living plants) than would be the case in a traditional classroom based botanical diversity exercise. Furthermore, Stokes and Boyle (2009) found that residential fieldtrips impact upon the affective domain of student participants which is in itself an important outcome of fieldwork and which also has the potential to enhance learning through the interaction of the affective, cognitive and psychomotor domains (see below). It is important therefore that, in the face of the various pressures which mitigate against field studies, the added value of field-based learning in an HE context be established.

Theoretical Context

> Fieldwork per se is relatively untheorized, but wider pedagogic theories can provide a useful framework in which to investigate the learning processes operating in a field environment. (Stokes and Boyle 2009, p 292).

In our experience the typical HE biological/environmental sciences field-based learning scenario consists of: a *preparatory phase* during which tutors provide an explanation of the tasks in hand, of methodologies to be followed and of outcomes to be achieved; a *doing phase* when students carry out the field-based tasks, responding here to the uncertainties of an uncontrolled field situation compared to the more predictable environment of the classroom/laboratory; a *reflective phase* during which data are assimilated and fixed within the contexts of prior learning and experience. The best field-based learning exercises will also facilitate an iterative approach which enables students to modify their practice upon the basis of their experience. In essence, therefore, field-studies are an example of experiential learning following Kolb's learning cycle (Kolb 1984) and the best examples of field based learning will enable students to progress through the stages of the cycle (Healey et al. 2005). We see the *preparatory phase* as being analogous to Kolb's abstract conceptualization, the *doing phase* as being analogous to Kolb's active experimentation and concrete experience phases, and our *reflective phase* as synonymous with Kolb's reflective observation. The degree to which each stage of the cycle is followed will depend upon the maturity of the learners within their subject discipline (e.g. first year students might be expected to undertake active experimentation within a rather more limited context than those in the final stage of their studies).

We also agree with the suggestion of Stokes and Boyle (2009) that fieldwork should be considered through the lens of Eiss and Harbeck's learning model (Eiss and Harbeck 1969). This suggests that each component of the full range of sensory inputs experienced during a learning activity has a discernable impact upon the affective domain of the learner which interacts with the cognitive and psychomotor domains to influence learning.

Taken together these models suggest that well designed fieldwork enhances learning and involves the developmental interaction of both the cognitive and affective domain of the student.

Research Question

We have noted in our own experience of biological sciences provision in HE, and through discussion with colleagues at a range of institutions, that there is a tendency for some elements of fieldwork to be replaced with virtual computer-generated exercises and/or laboratory based alternatives. Furthermore as class sizes have grown and transport costs have increased we have seen a shift away from students going into the field to collect specimens for identification (in situ or in a subsequent classroom based identification session) and for students to be *told* how to sample an environment rather than being *shown* how to—or preferably being allowed to *find out* how to through direct experience.

In essence there is developing a presumed equivalence of field-based teaching with laboratory and classroom activities but our experience of teaching students in the classroom, laboratory and the field has given us qualitative evidence that field teaching benefits student learning beyond that which can be achieved in other contexts. We are not aware of any quantitative validation of this. We therefore designed two authentic learning tasks with the same learning outcomes and differing only in that one of them incorporated a field study component. We took a small group of students through the two tasks and assessed their experiences and learning, aiming to:

1. compare aspects of the students' perceptions of field and laboratory work before and after involvement in the two learning tasks;
2. assess the two tasks in the context of the students' affective domain by comparing their perceptions of the value of the tasks;
3. assess the impact of the tasks on aspects of the students' cognitive domain by comparing academic achievement in the two tasks.

Methods

Our study, which was a combination of qualitative and quantitative approaches, involved 8 first year undergraduate students (4 men and 4 women) who were in the first year (Level 4) of one of the following BSc programmes at the University of Hull: Biology (1 student); Ecology (2); Coastal Marine Biology (3) or Environmental Science (2). The students were volunteers who had responded to an open invitation to their year group to participate in a research project which aimed to examine the value of practical work. At that stage no indication was given that the work would be field rather than laboratory based. This invitation attracted 14 volunteers. One week before the first practical exercise the students were told that they would be expected to do field work and should arrive properly equipped for working out of doors. At this stage 3 students dropped out, claiming competing work or study commitments). The day set aside for field work began with torrential rain and because of this only 8 of the expected students (11) turned up; it is likely therefore that the 8 volunteers who participated were well disposed to practical work in general and to fieldwork in particular before their participation in the project (although one of them had no fieldwork experience). We acknowledge that this prior fieldwork-friendly attitude of the students may have had an effect upon the outcomes of the study, in that the students were likely to reflect positively upon fieldwork. However, because of the experimental design employed in our study, we do not consider that this negates the value of the work and the conclusions drawn from it.

The Learning Tasks

The students completed two equivalent learning tasks one of which included fieldwork; both tasks required them to sort and identify the members of a community of invertebrates and make labelled and annotated drawings (see Appendix). The tasks were carried out by all students on two separate days.

The first task was completed in Dalby Forest, an extensive (32 km^2) commercial forest in the North York Moors National Park, NE England, and had a field based component. The students were taken to a stream and one of the tutors (RG) explained to them the principles of collecting stream-bed invertebrates through kick sampling (a standard method for freshwater invertebrate sampling). The kick sampling technique was then demonstrated by GS and PW. Student pairs were provided with a net and collecting pot and allowed to collect three separate samples. These were then pooled by each pair to form the collection of invertebrates that were to be examined (whilst alive) in the learning task. This field session lasted approximately 1 h. After a break for lunch the students were taken to a classroom setting within the forest and asked to complete the learning task over the next 3 h.

The second task was undertaken 2 weeks later in a teaching laboratory. There RG explained to them the principles of collecting sand dwelling invertebrates from the intertidal zone of the sandy shore. He and GS then demonstrated the relevant equipment in the classroom and explained how they had used it (sieving a volume of sand and transferring invertebrates retained by a 1 mm sieve into a collecting pot by backwashing) to collect a sample of the invertebrate community of a beach at Filey, NE England. The students were then provided with this collection (of dead organisms), which had been fixed in formalin and then stored in alcohol to prevent decomposition, and asked to complete the learning task over the next 3 h (the sample had been washed clean of alcohol and residual formalin prior to the session).

Task Authenticity

The learning tasks—collecting, sorting, identifying, drawing, labelling annotating—may, to a non-specialist, seem to be essentially descriptive and lacking the interpretative and evaluative contributions expected of HE students. However, in ecology and biological/environmental disciplines which include the study of biodiversity they are in fact key skills typically taught to first year undergraduate students. Basic knowledge about the identification of species is widely considered to be a fundamental for the understanding of biodiversity (Gaston and Spicer 2004; Randler and Bogner 2002; Randler et al. 2005). In the UK context the QAA Biosciences Benchmark Statement (QAA 2002), captures this through the requirements that graduates of Biological Sciences degree programmes should have experience in:

Table 1 The mean responses of 8 students to statements related to field and laboratory practical work and the results (*p* values) of Wilcoxon Matched Pairs tests to compare pre and post task responses to each of the statements

Statement	Mean rank ± SD pre tasks	Mean rank ± SD post tasks	*p* (Wilcoxon test)
Field work is something that I enjoy	1.22 ± 0.07	1.1 ± 0.33	0.37
Laboratory work is something that I enjoy	1.89 ± 0.33	2.11 ± 0.78	0.059*
I lose interest in fieldwork if the weather is poor	4.5 ± 4.38	4 ± 4	0.26
Field work is easy	3.11 ± 0.93	3.67 ± 0.87	0.10
Laboratory work is easy	3.5 ± 1.07	3.62 ± 0.52	0.71
Time in the field is time wasted	5 ± 4.75	4 ± 4.75	1.0
I would rather have lectures than do fieldwork or laboratory practical work	3 ± 1.32§	4.44 ± 0.96	0.059*
It would be better to listen to lectures about field biology than to do fieldwork	4.75 ± 0.46	4.61 ± 0.52	0.32
Fieldwork teaches me valuable skills	1.63 ± 1.06	1.38 ± 0.52	0.66
I learn most about the fieldwork topic in the field	1.75 ± 0.71	2 ± 1.07	0.71
I learn most about the fieldwork topic during the post trip write up	3 ± 1.07	3.13 ± 0.64	0.71
It would be better to work on material brought into the classroom rather than have to go into the field	4.75 ± 0.46	4.25 ± 0.71	0.11
I feel safe whilst undertaking fieldwork	2.13 ± 0.99	1.63 ± 0.52	0.16
I feel safe whilst undertaking laboratory work	1.86 ± 0.99	2 ± 0.54	0.71
I always feel well prepared for fieldwork	1.5 ± 1.88	2.12 ± 0.83	0.32
I would recommend fieldwork to others	2 ± 1.07	1.63 ± 0.52	0.18

§ n = 7

* Statistical significance at the 90% level

Student responses to the statements were recorded on a 5 point scale: 1 = agree strongly, 2 = agree, 3 = neutral, 4 = disagree, 5 = disagree strongly

> obtaining, recording, collating and analysing data using appropriate techniques in the field and/or laboratory (QAA 2002)

> and be able to:

> describe how organisms are classified and identified (QAA 2002)

> and:

> demonstrate comprehension and critical analysis of community structure, development, biodiversity, and associated models (QAA 2002).

Our learning tasks were designed to achieve (in part) the first two of these requirements. Typically both would be further developed in students throughout their studies culminating, at Level 6—their final year, in the achievement of the third.

Measurement and Comparison of Student Perceptions

To explore the perceptions of the students towards field and laboratory work (the first two of our three aims) they were asked to complete a questionnaire both before and after taking part in the learning tasks. The questionnaire asked the students to record on a 5 point Likert scale their level of agreement with a number of statements related to fieldwork, laboratory based practical work and formal lectures. These statements are included in Table 1. Pre and post levels of agreement were compared using two-tailed Wilcoxon matched pairs tests (Sokal and Rohlf 1981).

The second questionnaire also provided the students with an opportunity to write open responses to additional questions designed to provide an insight into their affective responses to the tasks that they had completed. These responses enabled us to understand the students' preferences for learning tasks or parts of tasks and to understand their perceptions of task ease, enjoyability and value.

Measurement and Comparison of Academic Achievement

To achieve the third of our aims and establish the level to which the cognitive learning of the students was influenced by the fieldwork component of each of our tasks we formally assessed the work that the students carried out.

The students each completed 5 assessments as part of each learning task. Three of these assessments were completed during each of the two practical days:

- assessment 1; production of an accurate, correctly arranged and correctly formatted, taxonomic list of the organisms that they sorted and identified;
- assessment 2; production of accurate drawings of 3 of the organisms identified;
- assessment 3; labelling and annotation of the drawings (annotations to include morphological features important in identification and features important in the adaptation of the organism to its particular mode of life).

The two further assessments were carried out under examination conditions 6 weeks after the task that included fieldwork and 4 weeks after the laboratory only task:

- assessment 4; production of written descriptions of the methods used to collect the invertebrate organisms encountered during the two learning tasks;
- assessment 5; labelling and annotation (morphological features important in identification and features important in the adaptation of the organism to its particular mode of life) of photographs of three of the organisms encountered during each of the two exercises (these may or may not have been the organisms chosen by the students to draw in their completion of assessment 2).

Objective marking criteria were developed for the assessment tasks by RG and GS.

The work carried out by the students during the field and laboratory days was marked by two experienced academics (MLT and SM); neither had been told the nature of our project and neither had any reason to assume from the student scripts that the mode of delivery of the two tasks differed in any way. The mean of the marks awarded to each student by the two assessors was calculated and this was used to carry out a comparative analysis of the achievement of the students using two-tailed *t* tests (Sokal and Rohlf 1981).

The post task assessments were marked by GS and check marked by a colleague (LJS) who had participated in neither the field nor laboratory tasks. The marks awarded to the students for the two learning tasks were compared using t-tests and Sign tests (Sokal and Rohlf 1981).

Throughout the work each student used an alias for identification of assessed work and questionnaires—this allowed reconciliation of assessed work and questionnaire to specific students while preserving anonymity.

Limitations of the Study

The small sample ($n = 8$ students) limited the quantitative analysis that could be carried out. However, by linking the quantitative analysis with extensive qualitative analysis we were able to address our primary research questions and to suggest directions for future study.

Results

Student Perceptions of Field and Laboratory Work

Student perceptions of field and laboratory work both before and after taking part in the two learning tasks are presented in Table 1. Student responses indicated, as we had supposed, that this group of students favoured practical work and fieldwork in particular. Perhaps as a consequence of this there was no strong evidence of a change in students' perceptions of field and laboratory work from before to after the tasks.

From their responses to the statements it is clear that although the students enjoy both fieldwork and laboratory work they enjoy the former to a higher degree. Comparison of the mean levels of enjoyment of fieldwork and laboratory work reported by the students prior to the tasks revealed a weak preference for fieldwork (Wilcoxon matched pairs test, $p = 0.059$), but this became more pronounced following their engagement with the tasks (Wilcoxon matched pairs test, $p = 0.02$). The students' high level of disagreement with the statements *I lose interest in fieldwork if the weather is poor* and *Time in the field is time wasted* and their neutrality to the statements concerning the ease of both field and laboratory based learning suggest to us that they are prepared to make a commitment to fieldwork and value it. This, together with their self declared high levels of enjoyment of this type of learning, is we believe connected to a clearly articulated preference on their part for practical learning over other modes. It is clear from Table 1 for example that these students do not think *it would be better to have lectures about field biology than to do fieldwork*. Nor would they *rather have lectures than do fieldwork or laboratory practical work*, an opinion that is clearly strengthened following their engagement with our learning tasks (Table 1). There is also a suggestion here that the students do not feel that classroom based work is a substitute for genuine fieldwork in that they disagree strongly with the statement *it would be better to work on material brought into the classroom rather than have to go into the field.*

Their perception of the value of fieldwork in the context of learning is further evidenced by their strong level of agreement with the statements that *fieldwork teaches me valuable skills* and *I learn most about the fieldwork topic in the field,* and their neutrality towards the statement *I learn most about the fieldwork topic during the post trip write up.*

Student Perceptions of the Two Tasks

Student Preferences

When asked to recall their *best memory* of one or other of the tasks all eight students described an experience related to the day that included fieldwork. Five of them described the collection of invertebrates by kick sampling as their best memory, often associating it with the word *fun*. One student described a social benefit of the experience valuing, *getting to know people on my course better*. One student stated that their best memory was *just being in the forest working outside*.

When asked to recall their worst memory of one or other of the tasks seven of the eight students recalled an experience linked to the laboratory only task (one student did not have a worst memory). Two main themes were reported; five of the students commented that the samples gave off an unpleasant odour, and two of them commented that they had found the animals collected from the sandy shore difficult to identify.

When asked to state which of the two tasks they *found the most difficult* the majority of the students (six) said that it was the laboratory-only task. Their reasons varied with some students citing difficulties in identifying the organisms, some describing a lack of motivation to engage with the task and one of them commenting that the laboratory-only task was the most difficult because *it was not the full process* (which we infer as being an acknowledgement that not having collected the material ones self diminishes the value of the exercise). One student thought that both tasks were equally difficult because of *no previous experience identifying animals using keys*.

Only one student felt that the task which included fieldwork was the most difficult, although this student's response was qualified by; *Dalby morning was good* (the fieldwork) *but the task of identifying in the afternoon* (classroom based work) *made the day quite long, this made the whole process quite tiring*. As would be expected this student made a similar judgement when asked which of the tasks was preferred, stating *I enjoyed the Scarborough day* (laboratory-only task) *as it was a short day which made the tasks easier to perform. Although Dalby was very interesting the fuller day was tiring*.

The other seven of the group all preferred the task involving fieldwork, two of them stating that fieldwork was more *fun* and six of them stating that their preference was a result of their having first hand experience of the whole process of field based sample collection and classroom based sorting and identification of the collected organisms.

Student Perceptions of Task Value

We asked participants to consider the value of the two learning tasks in the contexts of their learning whilst at university, their life-long learning following graduation, and their career aspirations. In all three contexts seven of the eight students stated that the exercise involving fieldwork had the greatest value.

In terms of their learning whilst at university some students cited a perceived subject fit as being the main reason for their choice. For example the student who felt that the laboratory-only task had the greatest value stated that this was because *my area of study will be marine based.* Similarly one of the students preferring the exercise involving fieldwork task stated *I intend to … study … woodlands.* The remaining students all raised themes related to the *completeness* of the field based task, to the *learning of techniques* and to the task providing an ecological context for the animals identified.

Similarly, when providing arguments in support of their perceptions of the relative value of the two tasks in terms of their life-long learning following graduation a number of students discussed the subject fit of the task and their academic area of interest (one who preferred the laboratory task was a marine biologist and three with an interest in terrestrial biology preferred the fieldwork task). However, two students, who both attributed greater value to the day which incorporated fieldwork, discussed the opportunity for social interaction that a field based exercise provided. One stated that *field-work involves more group interaction* and *develops social skills better*; and one student cited *health and safety*, *working together*, *meeting new people*, *being outside rather than inside all of the time* as factors adding value to the field day.

These themes were extended when students considered task value in the context of employment. The students who had previously linked value to a clear subject focus continued to do so, one student valued the laboratory task because [my] *career aim is marine based rather than freshwater based*, and three valued the fieldwork because they wanted to either work in woodlands or work in an environment where experience of field skills would be important (*a field study centre* for example). Two students explained that the integrated field and classroom task included what they described as *transferable skills* unfortunately without explaining what they meant by this, but based upon their responses to other questions it is likely that they were referring to specific ecological/biological practical techniques rather than generic skills. Three students discussed their view that field work promoted social interaction and enhanced inter-personal skill development and one student who extended this argument hoped to become a school teacher and considered that the task that had included fieldwork had greater value because it *shows me that people work together*, *meet new people and enjoy themselves when they are having fun and doing something they find interesting. Also* [I] *had to think about* [the] *safety aspect*.

Academic Achievement

Table 2 shows that the students were slightly better able to construct a taxonomic list when they had themselves collected the animals as part of a task that included fieldwork ($p < 0.1$). There was, however, no meaningful difference in their ability to draw or label and annotate their drawings. However, following a period of reflection of 4–6 weeks the students were better able to recall and describe accurately a field-based animal collection method that they themselves had carried out ($p < 0.05$)), and were slightly better able to label and annotate photographs of organisms that they had themselves collected ($p < 0.1$).

Discussion

Are learning tasks which *involve* students in fieldwork equivalent to those which *inform* students about fieldwork? There is a strong feeling amongst those involved in field based tuition that they are not and that learning is enhanced in the field (Manzanal et al. 1999; Maskall and Stokes 2008; Smith 2004; Tilling 2004), especially when fieldwork involves experiential learning (e.g. Millenbah and Millspaugh 2003). As practitioners we share this view but we also acknowledge, in the face of a plethora of pressures acting upon our education systems, that our expression of a *strong feeling* is insufficient and that the value of fieldwork must be established.

Our case study demonstrated that a task involving fieldwork, and one in which fieldwork was discussed but not carried out, were not perceived as being equivalent by students. The students were quite emphatic in their view that lectures, classroom activities and laboratory-based practicals which involve fieldwork topics are not an adequate substitute for an authentic fieldwork experience.

This is significant because in the context of fieldwork the perceptions of students are known to influence both their motivation to engage with a learning task and by extension, therefore, with their academic achievement (Boyle et al. 2007; Stokes and Boyle 2009). Our students reported that they enjoy fieldwork and they value it (in the contexts of both their learning at university and life-long learning, and in relation to their career aspirations). They also have a perception that they learn more effectively in the field. When expressing their preference for fieldwork over classroom-based learning our students linked the concepts of *fun*, *ease*, *motivation*, *relevance* and *achievement* to *being out of doors*, *developing key subject skills/knowledge* and *developing social skills/networks*. Taken in the round these views support the idea that an experience of fieldwork, even one of short duration, has a positive impact upon the affective domain. This finding supports those of Boyle et al. (2007) and Fuller (2006) who demonstrated a positive impact of both residential and day excursion fieldwork upon the affective domain of HE Geography students at a wide range of UK universities and at Massey University, New Zealand, respectively. Comparison of the key themes raised by our students and those raised by the Geography students taking part in these cited studies indicates that there are clear similarities in the needs/preferences of students across disciplines. This emphasizes the merit in taking a cross-disciplinary (and international) perspective in future investigations into the value of fieldwork and in the further development of a pedagogy of fieldwork.

We anticipated that a positive impact of fieldwork upon the affective domain of the students would influence their subsequent cognitive development (based upon Eiss and Harbeck 1969) and we have indeed demonstrated that the inclusion within a learning task of fieldwork that is perceived by students as a positive experience can enhance aspects of learning. Our students were better able to construct a taxonomic list of organisms that they had collected themselves and they were better able to recall the structural detail of organisms that they had collected in the field in comparison to organisms provided by tutors. At this point however, it is important to consider another potentially

Table 2 Mean marks awarded (±SD) for academic achievement of 8 students

Assessment	Mean mark ± SD for task that included fieldwork	Mean mark ± SD for laboratory-only task	t
1 (taxonomic list of invertebrates)	13.06 ± 4.51	10.06 ± 2.55	2.25*
2 (drawings of invertebrates)	22.88 ± 6.23	21.0 ± 5.27	0.67^{NS}
3 (labelling and annotation of drawings)	4.44 ± 4.61	3.75 ± 2.83	0.57^{NS}
Sum of assessments 1, 2 and 3	40.38 ± 13.18	34.81 ± 8.63	1.15^{NS}
4 (post-task description of methods)	6.0 ± 2.0	3.5 ± 1.85	2.82**
5 (post-task labelling and annotation of photographs)	14.61 ± 6.4	10.13 ± 4.8	1.98*
Sum of assessments 4 and 5	20.61 ± 7.5	13.63 ± 5.4	2.68**

Assessments 1, 2 and 3 were completed during two laboratory sessions, one of which had been preceded by fieldwork. Assessments 4 and 5 were completed under examination conditions 4 and 6 weeks later. Two-tailed t tests were used to compare means marks between the two tasks (t). * $p < 0.1$, ** $p < 0.05$ and ^{NS} $p > 0.1$

significant difference between our two learning tasks. One of them (the task including fieldwork) exposed the students to living material whereas the task that did not involve fieldwork only gave them the opportunity to engage with preserved material. Had it been logistically possible to provide living material as part of the task that did not include fieldwork the students may have engaged more effectively with that task. It is axiomatic, however, that in general the opportunity to engage with living animals is an integral part of fieldwork while the use of preserved material is the norm for laboratory-based work.

An enhanced memory effect was evident in the ability of the students to recall the detail of a field methodology that they had personally experienced rather than one that a tutor had described to them in a classroom setting. That fieldwork enhances memory has also been suggested by Braun et al. (2010) who found that after a similar time period (3–4 weeks) students were better able to recall facts about a species that they had first hand field-based experience of. This memory effect is consistent with the idea that fieldwork, following an experiential learning model, promotes deeper learning (Kolb 1984). The focus of our project was the effectiveness and equivalence of the two modes of teaching in enabling the students to achieve our learning outcomes rather than an exploration of the potential of fieldwork to foster deeper learning *per se*. However, through their open responses to our questions concerning the value of fieldwork three students have provided us with an insight into the possibility that deeper learning has occurred in that students were able to contextualise their learning in terms of reflection upon their own abilities and to extend their learning to form links between newly acquired skills/knowledge and related concepts (lifelong learning, career development) that were not necessarily the focus of our tasks. It is our aim to develop a new research instrument to explore this possibility further. For example three students stated that the fieldwork experience was valuable:

> Because I *know* how to kick sample *confidently* and won't forget. Because I don't know how the sandy shore invertebrates were collected so this doesn't help, whereas I *know* how to kick sample. Student 1. (our emphasis).
>
> Collecting helped me *understand* the invertebrates environment. Student 2. (our emphasis).
>
> [Dalby] was very interactive and we went through the whole process from collection to identification. I was able to *understand* what I had to do better. It can be *applied* to many situations and contexts. Student 3. (our emphasis).

We interpret these comments as further evidence that the students are making reflective links between self realisation, self confidence and ability. In the context of Bloom's taxonomy they are demonstrating *knowledge*, *comprehension*, *application* and perhaps *analysis*, in the context of the cognitive domain (Bloom 1956). Through direct experience of the organisms in situ students 2 and 3 were able to link taxonomy and biodiversity to ecology and the environment even though this was not an explicit aim of the task. As an example of *relational* understanding (Biggs 1999) this is perhaps an indication of higher level (or deeper) learning being brought about through an authentic field experience.

It is our conclusion, therefore, that our findings highlight the value of an interaction between the affective, psychomotor (the physical experience of doing the field work) and cognitive domains during a task that included fieldwork (in support of Eiss and Harbeck 1969). In essence this case study highlights one of the key values of field-based teaching, i.e. that students can learn about aspects of biodiversity more effectively in a fieldwork context.

In the wider context we have suggested that environmental literacy is key to society's response to the current environmental crisis. The ability to recognise animal species is central to the preservation of biodiversity because the species is the fundamental unit of biodiversity (Randler 2009). However, there is growing concern about people's inability to recognise even common plants and animals (e.g. Bebbington 2005; Evans et al. 2006) and it has been suggested that work with living organisms is essential to the enhancement of biological education (Lock 1994; Strgar 2007). Based upon the findings of Taraban et al. (2004) that students learn better when exposed to living material, and our own finding that they are better able to sort, group and describe living organisms that they have collected themselves, it is therefore vital that fieldwork is retained as a central component of environmental education at all levels of study and we agree wholeheartedly with the sentiment of Barker (2005) that "Fieldwork is THE authentic context for teaching ecology".

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Appendix: The Learning Exercise as Presented to the Students

Learning About Invertebrates Through Sorting and Interpreting Collections

Learning Objectives

Students who have completed the exercise will be able to:

1. Sort a collection of invertebrates from a specific habitat into taxonomic groups on the basis of characteristic morphological features, aided by relevant literature including keys and illustrated guides.
2. Identify and classify the principal animals in the collection to the level of phylum, class, order and where possible family and genus.
3. Demonstrate their knowledge and understanding of the collection by:

   a. Making a list of the animals present which will include their phylum, class, order and where possible family and genus, with brief notes on the principal morphological features that allow the classification of each of the animals present.
   b. Making line drawings of three animals with comprehensive descriptive labelling and annotations, the annotations to include comment on morphological adaptations to the animals' specific habitat.

The Learning Exercise

Please work in pairs. The following tasks should be completed.

1. Each pair will begin with a mixed collection of invertebrates that have been collected from one habitat. The pair should sort the collection into the different types of animals present. Individual animals can be transferred using a wet brush from the main collection to Petri dishes, using separate Petri dishes for each taxon.
2. Next the animals can be identified and classified to the level of phylum, class, order and where possible family and genus. Appropriate guides and keys will be provided to help with this task; students may consult one another and the staff.
3. Each student should *individually* prepare a list of the animals in the collection. This should reflect the classification of the animals and for each animal should include: (a) its phylum, class, order and where possible family and genus, (b) brief notes to describe the characteristic morphological features that helped you with identification and classification.
4. *Each student* should make an accurate and precise pencil drawing of each of *three* of the animals. Use a separate sheet for each drawing. The drawings should be fully labelled to draw attention to features of interest and importance. The drawings should also be annotated with additional biological information about the specimen. The annotations should include information on how you think the animal is morphologically adapted to life in its specific habitat.

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Written evidence submitted by University of Hull (Sch Sci 17)

Summary

As practitioners in higher education, scientific researchers, employers of people in the environmental sector and researchers into the role of education in the field we consider that practical work and in particular, field-based practical work has a vital role to play in school science teaching. The key points of our submission are as follows:

- There is clear evidence that field-based teaching is more effective for teaching students about their environment than classroom-based teaching.
- We perceive a gap between skills required for scientific research and other employment and those that school leavers and graduates receive as part of their education in the environmental sciences.
- We are aware of a perception that fieldwork in schools is in decline, though not of any hard evidence to support this. However, it is possible that there has been a shift in the availability of opportunities for fieldwork, such that it is present and widespread in some schools and absent in others.
- We consider that the major barrier to widespread field-based teaching in schools is the lack of knowledge, experience and confidence among teachers of how to safely plan field visits, including complying with health and safety requirements, rather than the requirements themselves.
- The consequences of a further decline in fieldwork in schools would be: a reduction in environmental awareness amongst school leavers and hence the public at large; a requirement for universities to carry out more basic training of students in field and practical skills; a progressive decline in capacity to deliver field-based teaching among teachers at school and university level.
- We recommend that training be provided for both school teachers and university lecturers in field teaching, including planning and managing field courses.
- There should be a move to integrate science-based field and practical activities across the wider school curriculum.

1. Introduction

1.1 We are higher education (HE) practitioners, field scientists and researchers into education (from primary level to HE) in the biological sciences. We are particularly involved in education and research in field situations and in research into the role of field-based education. As university lecturers we recruit and teach students who are the product of school education. As field scientists we carry out original research in ecology and the environment, often with the assistance of undergraduate and postgraduate research assistants. As heads of department we are involved in the employment of people in technical and academic roles, many of which require practical or field-based ability. As researchers in education we are investigating the effectiveness of field-based teaching to students from primary schools to universities and its wider educational value. Our submission is therefore based on our personal experience of teaching students at all levels, our experience as employers of scientists and educators and evidence from research we have carried out examining the value of education in field situations. Our primary expertise is in the role of field courses and field-based teaching, rather than laboratory practicals. We have therefore concerned ourselves in this memorandum with discussion of field-based teaching and have not responded to questions (such as on exam boards and schools outside England) where we do not have experience.

2. How important are practical experiments and field trips in science education?

2.1 We consider that practical work and field-based practical work in particular is extremely important across areas of science education, and particularly in the 'environmental sciences' which generally encompass the traditional disciplines of biology and geography and areas where these two overlap. There are two broad areas of importance: Effectiveness of education and benefits to individuals and society.

2.2 Research examining the value of fieldwork (Scott et al. 2011a) has shown that undertaking practical exercises in the field improves student engagement in the activity and as a consequence improves their ability to recall concepts and carry out intellectual and practical tasks relevant to the environment they have studied. There is good evidence from a wide range of literature in education that the context in which learning takes place affects the effectiveness with which students learn, so we should expect (as we observe) that learning about the environment *in* the environment is more effective than learning that takes place removed from the environment.

2.3 We also consider that students perceive learning where they carry out tasks and are involved in the process of enquiry and discovery as being more authentic.

2.4 We understand that practical learning in the field (but also in the laboratory) permits us as tutors to foster learning autonomy in our students. We have provided evidence that this autonomy results in stronger engagement with learning tasks. (Goulder and Scott 2009).

2.5 Learners' development tends to progress from basic tasks such as learning to repeat information presented to them to being able to compare, contrast and evaluate ideas. Field-based learning introduces elements of uncertainty into the learning environment, and understanding how to deal with this uncertainty is a vital part of the wider cognitive skills that students ought to develop through their education.

2.6 Field courses, particularly residential ones, have an important pastoral role to play that is often not recognised. The social context in which learning takes place is a key component of its effectiveness. Field courses can help to build bonds between students and their peers and students and teachers which lead to a better learning environment both during the course and beyond in the student's wider education at school.

2.7 We also consider that field-based teaching is a key tool in embedding an awareness of the environment in all school students. Such an awareness ought to be part of basic scientific and environmental literacy, vital to a wider understanding of the importance of environmental issues to society. It is difficult to see how this might be achieved without students experiencing the environment for themselves.

2.8 Field-based learning has the ability to impact upon both the cognitive learning (i.e. students' ability to learn information) and affective learning (their awareness of and feelings about their surroundings) in a powerful and integrated way. This complete learning experience can, we feel, lead to enhanced learning and the development of students beyond the confines of their discipline specific knowledge base (Scott et al. 2011a, Goulder and Scott 2009, Scott et al. 2011b)

2.9 As recruiters of individuals in the environmental sector we are aware that field skills are in short supply amongst many candidates for technical and research positions, despite their relevance to strategic priorities of UK research councils and to national agendas. This indicates to us that the body of individuals seeking employment does not adequately meet the demand for these skills. A similar message has recently emerged from employers in the environmental sector who describe a series of 'critical skills gaps', many of which are field-based.

3. Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

3.1 There is a widespread perception in the literature on fieldwork in education that there has been a decline in the quantity of field-based teaching. However, we do not know of any hard evidence that details this decline, at least at higher education level. Nevertheless it appears that in some areas of teaching, fieldwork is no longer as prevalent as it may have once been. Conversely, some practitioners with enthusiasm for and an interest in fieldwork are promoting and increasing fieldwork opportunities for students at school and university. The breadth of opportunities now available for fieldwork for school students from third party providers such as Operation Wallacea and BSES expeditions (who run field activities for schools in a variety of tropical and polar environments) is indicative of both the opportunities available, and more importantly of the desire for fieldwork amongst schools and school age students. However these activities typically take place during school holidays and at a significant cost, so participation in them is based on teachers' enthusiasm to participate and parents' or schools' ability to pay. We cannot therefore rely upon the private sector to provide an equitable opportunity to our pupils and students.

3.2 Regularly quoted reasons for declining fieldwork are the administrative burden, rising costs, lack of space in crowded curricula and health and safety issues. Our personal experience from discussions with teachers is that teachers perceive these issues to be bigger barriers than they are. We see the major problem being a lack of training amongst teachers in how to deal with issues such as health and safety and risk assessments. Our experience as heads of department and budget holders is that at least in universities the real costs of fieldwork compared to laboratory work are not well understood (this might therefore be a priority for future research).

3.3 In a crowded curriculum fieldwork, which appears to be costly and time consuming, may be squeezed out (particularly to make way for national initiatives around core subjects which do not take into account the local context). However, learning in the field presents opportunities for education beyond the environmental sciences and fieldwork can be co-opted for teaching across the school curriculum (literature, art, history are obvious examples). Primary school students in one of our studies (Scott et al. 2011b) who carried out field-based activity linked to local biodiversity had improved writing skills, demonstrating a link between science education in the field and literacy.

3.4 We are also aware, as heads of university science departments, that the strategic drivers of research in the biological sciences have led to a shift in the nature of academic departments towards a much greater focus on molecular and laboratory skills. This shift has necessarily led in some areas to a reduction in academic staff willing and able to deliver field-based teaching which will in turn have an impact on the ability of graduates, many of whom go in to science education, to teach in the field themselves, perpetuating a spiral of decline.

4. **What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?**

4.1 There is a widely held perception that health and safety concerns are a major barrier to the delivery of field teaching, but the fact that students at all stages are able to participate in fieldwork in a range of remote and challenging locations, as well as within the UK with due consideration given to health and safety, demonstrates that these problems are managed as a matter of course by many. As we discuss above, we consider that the lack of confidence stemming from a lack of training amongst teachers in how to manage health and safety issues is a greater barrier to field-based teaching than the health and safety concerns themselves.

5. **If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?**

5.1 In our roles as university lecturers, we receive students from school without many of the basic laboratory and field practical skills that we might previously have expected. Time must therefore be spent developing these skills. On the other hand, most students now arrive at university with very good ICT skills and time previously spent teaching these can be used to deliver practical skills.

5.2 There is an assumption that a lack of exposure to fieldwork at school reduces a student's likelihood to follow a university degree programme relevant to fieldwork, but evidence from our current research suggests that this is not necessarily the case: students who choose degree programmes and modules with significant fieldwork components are not predominantly those who had experience of fieldwork at school. We consider this area to be a priority for future research.

5.3 A lack of fieldwork at school may have a series of less obvious effects on students' learning. Specifically, those benefits that are realised through field teaching discussed in section 2 will be diminished.

6. What changes should be made?

6.1 In order to embed field-based teaching in the school curriculum there should be a programme of training for teachers at all levels (including HE) to provide them with the basic skills to deliver and manage teaching in the field.

6.2 We would advocate support for solid research to support or dispel the assumptions described above and to investigate the wider value of fieldwork across the school curriculum.

6.3 We would recommend that in schools fieldwork is integrated across the curriculum rather than being restricted to the biological or geographical sciences. Field visits must be used to their fullest as tools for learning about the environment, society and the arts and core skills such as ICT, numeracy and literacy should be taught in conjunction with field based science through carefully designed field based learning exercises.

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Introduction

1. As a leading UK awarding body, OCR designs, produces and assesses qualifications, particularly GCSEs and A Levels, but also a wide range of vocational and basic skills qualifications. We meet the needs of learners of all ages, working with 13,000 schools, colleges and other institutions. These close links with curriculum and learning have made us very aware of the impact of the current assessment of practical work in science.

How important are practical experiments and field work in science education?

2. For most students, it is the practical and investigative work that makes science distinctive within the school curriculum. When taught well, practical work in science has the 'awe and wonder' that no other subject can match. There can surely be no doubt of the importance of practical work in capturing the interest and enthusiasm of students.

Do examination boards adequately recognise practical experiments and field work?

3. Assessment of experimentation in the laboratory and field work is naturally limited by the need to allow tens of thousands of students across the country to undertake similar work and gain similar results. This work has to not only enable them to learn something but also needs to be assessed on a similar scale, enabling the same marks to be given for the same outcomes.

4. This 'natural' assessment limitation is then further tightened by a bureaucratic limitation. In order to be accredited by the exams regulator, Ofqual, qualifications such as GCSEs and A Levels need to meet stringent criteria related to both design – which include the methods of assessment of practical work – and content. These criteria have in the past been determined by the Qualifications and Curriculum Development Agency (QCDA).

5. Within high stakes qualifications such as GCSEs and A Levels, the assessment of practical work is tightly controlled (by the criteria) and, as a consequence, the range of practical work that is assessed is highly constrained. This in turn constrains teaching and learning in many schools and the result is that the practical element of these courses tends to become formulaic and dull.

6. Coursework (and in the future Controlled Assessment) is the favoured approach but schemes of assessment in many cases assess the skills of the teacher in preparing candidates rather than the abilities of candidates themselves and offer poor discrimination.

7. The genuinely practical skills of manipulating apparatus to do an experiment, taking observations and measurements, and the 'softer' skills of collaboration with others and personal organisation are not tested within the current

framework of GCSEs and A Levels. This is because they do not generate written evidence and therefore don't meet the qualification criteria which are set centrally. However, it is these skills that are particularly valued by both employers and higher education.

8. Each time specifications are re-developed (at the behest of agencies such as Ofqual), the criteria that the qualification has to then meet require a different model of practical assessment. These are introduced without prior testing or piloting, as the timescales for development are always very limited.

9. In addition, there is no consensus within the science community about what skills should be developed and even less about what can or should be assessed.

10. OCR has expressed its concerns about this over a number of years. We have argued for courses which encourage teachers to provide students with an experience of a wide range of practical activities, including the development of practical skills, investigative work modelling the scientific process, and field work. OCR believes that internal assessment of these activities is not the best or only way of encouraging them and that much more could be achieved with external assessment of the 'thinking' rather than the 'doing'. It is likely that a combination of approaches, properly researched and piloted, offers the best way forward, enabling young people to discover the full excitement of practical work in science.

Oxford, Cambridge and RSA Examinations (OCR)

11 May 2011

Written evidence submitted by The Linnean Society of London (Sch Sci 19)

We are writing on behalf of the Linnean Society of London in response to the inquiry into practical experiments in school science lessons and science field trips.

The Society is not in a position to address all of the individual questions posed by this inquiry but has a long-established interest in the continued provision of practical experimental work within the laboratory and the field. Scientific work, and hence training, has practical work at its core and the early acquisition of laboratory and field skills is essential preparation for those students who wish to pursue scientific study at an advanced level and/or move into scientific careers.

In recent years, much concern has been expressed at the decline in practical work within schools and universities and the resulting depletion of the skills base of those looking for jobs in relevant sectors post-graduation. The concern about declining skills is not just restricted to those seeking employment; biological recording in the UK is heavily-dependent on volunteers, many of whom acquired their initial skills and interest within their formal education. This volunteer population is ageing and there is concern that today's young people will not have the skills to generate the biological records that are so essential to the monitoring that contributes to UK, European and International biodiversity targets.

The decline in field skills was noted in the House of Lords Systematics and Taxonomy inquiry (2007-2008) who recommended that "field study trips...should be encouraged as a means of engaging and stimulating young people (as future volunteers) in biological recording" and highlighted the need for the inclusion of more biodiversity-related topics within the curriculum. We strongly agree with this recommendation.

For many years, health and safety concerns have been flagged up as an "explanation" for the decline in laboratory and fieldwork within many schools. We believe that there are many ways in which students can carry out practical work, particularly within the field where many experiments are observational with minimum identifiable hazards.

Professor David Cutler and Dr Ruth Temple
The Linnean Society of London
10 May 2011

Written evidence submitted by Office of Qualifications and Examination Regulation (Ofqual) (Sch Sci 20)

1. Ofqual's role is to regulate qualifications and assessments in England and vocational qualifications in Northern Ireland. To regulate the quality and standard of qualifications, Ofqual and its fellow regulators set requirements which must be met by recognised awarding organisations and the qualifications they award.

2. GCSE science qualifications have had a high profile in recent years, following the serious cause for concern we found when monitoring the version of the qualifications used in 2007 and 2008. Ofqual has now set new criteria for GCSE science, and has accredited new GCSEs for first teaching in September.

3. This submission to the Science and Technology Committee inquiry into practical experiments in school science lessons and science field trips covers the following issue: Do examination boards adequately recognise practical experiments and trips?

Background

4. On 1st April 2010, the Apprenticeships, Skills, Children and Learning (ASCL) Act 2009 formally established Ofqual as a non-ministerial government department which reports directly to Parliament and the Northern Ireland Assembly. Ofqual had existed in interim form since 2008. The current Education Bill proposes changes to Ofqual's objectives and governance.

5. Ofqual regulates and maintains standards by recognising awarding organisations. Only recognised awarding organisations can offer regulated qualifications. All organisations registered can be found at the Register of Regulated Awarding Orqanisation and Qualifications: http://register.ofqual.gov.uk/

Do examination boards adequately recognise practical experiments and trips?

6. Regulated qualifications must meet the relevant criteria produced by Ofqual. The current criteria for GCSE and GCE sciences both emphasise the skills requirements that are gained through practical investigations and the need for them to be included in the course of study and assessment. For example, in GCSE Science the following are included:

   Aims and Learning Outcomes:

   - *develop their awareness of risk and the ability to assess potential risk in the context of potential benefits*
   - *develop and apply their observational, practical, enquiry and problem-solving skills and understanding in laboratory, field and other learning environments.*

   Assessment Objective 2

   - *Apply skills, knowledge and understanding of science in practical and other contexts.*

7. Likewise, in GCE (A level) criteria for science subjects the following are included:

   Specification content

   - *Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.*

   Assessment Objective 3

   Candidates should be able to:

   a. demonstrate and describe ethical, safe and skilful practical techniques and processes,
   selecting appropriate qualitative and quantitative methods

   b. make, record and communicate reliable and valid observations and measurements
   with appropriate precision and accuracy

c. *analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.*

8. The criteria do not specify what experiments must be carried out. Nor do the criteria specify that there must be field trips or, indeed, what constitutes a field trip. We are aware that some schools and colleges use their local surroundings to carry out investigations; others take planned (but perhaps costly) trips to field centres.

9. In summary, the criteria make clear the expectation that learners will experience and acquire experimental skills. But the details of what should be required is left to the awarding organisations responsible. They, in turn, write their specifications to embody sufficient flexibility to enable each school and college to meet the requirements within their constraints of their resources, geographical location and expertise.

Office of Qualifications and Examination Regulation

11 May 2011

Written evidence submitted by Research Councils UK (RCUK) (Sch Sci 21)

1. Research Councils UK is a strategic partnership set up to champion research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more effectively to enhance the overall impact and effectiveness of their research, training and innovation activities, contributing to the delivery of the Government's objectives for science and innovation. Further details are available at www.rcuk.ac.uk

2. This evidence is submitted by RCUK and represents its independent views. It does not include, or necessarily reflect the views of the Knowledge and Innovation Group in the Department for Business, Innovation and Skills (BIS). The submission is made on behalf of the following Councils:

   Arts and Humanities Research Council (AHRC)
   Biotechnology and Biological Sciences Research Council (BBSRC)
   Engineering and Physical Sciences Research Council (EPSRC)
   Economic and Social Research Council (ESRC)
   Medical Research Council (MRC)
   Natural Environment Research Council (NERC)
   Science and Technology Facilities Council (STFC)

3. RCUK, as part of its Public Engagement with Research strategy[1] has a commitment to '*inspiring young people to help secure and sustain a supply of future researchers to support the research base that is critical to the UK economy by encouraging engagement between young people and researchers*'. A key aim of this strategy is to enhance the experience of contemporary research for young people and school teachers, encouraging more people from a diversity of backgrounds to pursue relevant studies beyond 16 and follow R&D careers and enabling more to act as informed citizens. Alongside the collective RCUK ~ £1 million schools programme, individual Research Councils also have a number of schools activities under this aim.

4. The evidence gathered for this inquiry focuses on points one to three in the Terms of Reference in particular, regarding the importance and state of play for practical experiments and field trips in science lessons. However, it also includes information relevant to the other areas of the inquiry and the value that RCUK can add in this area.

5. RCUK endorses the findings from the BIS Science and Learning Expert Group[2] that '*practical work is one of the defining features of scientific observation and enquiry'* and that more could be done in this area both within and outside science lessons, primarily though practical work and extra-curricular enrichment. The report highlights that there is consistent evidence that the extent and quality of practical activity is an important factor affecting students' attitudes to science and shows universal agreement from stakeholders contributing to the report in the value of high-quality practical work in

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[1] Research Councils UK Public Engagement with Research Strategy
http://www.rcuk.ac.uk/documents/scisoc/RCUKPERStrategy.pdf
[2] Report of the Science and Learning Expert Group (February 2010)
http://interactive.bis.gov.uk/scienceandsociety/site/learning/files/2010/02/Science-and-Learning-Expert-Group-Report-Annexes-31.pdf

increasing engagement and motivation in learners. The Teaching and Learning Research Programme[3], which received funding from ESRC, also highlights the importance of recognising the significance of informal learning, such as learning outside of school, and recommends that is should be at least as significant as formal learning. It also suggests that systematic efforts must be made to increase the use of out-of-school activity in the learning of science.

6. RCUK considers that practical experiments and field trips are able to help bring science to life, making it fun and enthusing. However, it also improves attainment by developing learners' scientific skills, knowledge and conceptual understanding and helps to root science in the 'real world' and show how scientific theory might be used in a laboratory or university. This is reinforced by findings from Ofsted[4], who have concluded that those schools '*with the highest or most rapidly improving standards ensured that scientific enquiry was at the core of their work in science. Pupils were given the opportunity to pose questions, and design and carry out investigations for themselves'*. For example the STFC supported Faulkes Telescope Project provides access to telescopes and accompanying educational resources so that pupils in 900 schools are addressing real science problems and are developing experimental skills from the classroom, including critical thinking, team work and ICT skills.

7. The importance of exposure to the 'real world' is also evident as it teaches students valuable skills and learning in citizenship. For example in March 2011 as part of the ESRC festival of Social Science, pupils spent a day in the Peak District National Park, where they spent the day studying soil quality vegetation cover and water tables to examine how we affect the moorland and how it reacts to global warming. As a result of the project pupils had an increased sense of ownership and responsibility for their local environment and the National Park, and how it links to the global challenge of climate change.

8. The report by the BIS Expert Group supports findings from a report from SCORE[5] on practical work in science, which highlighted that although there is a wide range of practical work taking place across the UK, quality is uneven. This report identifies the following factors as affecting the quality of practical work in science: well-planned and effectively implemented teaching; confidence levels of teachers; shortcomings of equipment; perceptions of restrictions imposed by health and safety; pupils' behaviour; and lack of technical support. The expert group agreed that the first two of these factors has the strongest influence, with both teachers and learners believing that specialist teachers provided the most stimulating, original and developmental practical work, and were more able to link theory and practice effectively. As well as the recruitment of specialist teachers, CPD and support from technicians were seen as vital for improving the confidence of teachers and quality of practical work. RCUK has received similar feedback from teachers and would agree with these findings.

9. RCUK is keen to add value in this area, given its unique access to cutting-edge research and researchers. To this end, RCUK funds a programme of Teacher Continuing Professional Development (CPD) entitled 'Bringing Cutting-edge Science into the Classroom[6]', which is designed to help secondary school teachers deliver some

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[3] The Teaching and Learning Research Programme http://www.tlrp.org/

[4] Ofsted, June 2008, *Success in Science* http://www.ofsted.gov.uk/Ofsted-home/Publications-and-research/Browse-all-by/Post-16-learning-and-skills/Read-about-this-new-section/Curriculum/Success-in-science

[5] SCORE; December 2008, Practical Work In Science: A Report And Proposal For A Strategic Framework http://www.score-education.org/media/3668/report.pdf

[6] Bringing Cutting-edge Science into the Classroom: http://www.slcs.ac.uk/cuttingedge

of the more challenging aspects of the curriculum in a way that captures and retains the interest of learners. It is also designed to support teachers' development of specialist knowledge and to facilitate links between teachers and contemporary research.

10. The 'Earthquakes and Natural Hazards' course is part of this CPD programme, and has been delivered to approximately 90 teachers. The course was developed and delivered in collaboration with NERC's British Geological Survey's School Seismology Project[7] which enables schools to collect and use data from large earthquakes happening anywhere in the world to understand basic science concepts. In terms of encouraging students to participate in practical science this has been very successful. At the 2011 Big Bang Fair, the IOP Prize for best physics project was awarded to a project working with data from their school's seismometer system.

11. The evaluation of the Bringing Cutting-edge Science into the Classroom courses has been excellent. However in England the Government's 'rarely cover' policy issued to schools has made recruiting the target number of teachers challenging. Feedback has been that where schools have a number of conflicting priorities contemporary science courses are viewed as a luxury, where they are limited to the amount of CPD they can take part in outside of school. In response to this RCUK has offered twilight and weekend courses, but 'rarely cover' remains an issue. RCUK has a contract with the Science Learning Centre Network to deliver these courses until July 2011 and will be reflecting on the government White Paper[8] and its implications for CPD going forward.

12. The Expert Group also highlights the importance of practical and project work as part of a diverse toolbox of methods and approaches to accommodate different learning styles and to give students the attributes they require including a combination of theoretical, practical, experimental and factual learning. Opportunities for enrichment of STEM education outside of the classroom are also highlighted as important ways of engaging young people and in delivering the skills and experiences that are needed to underpin later study and employment for the future prosperity of the UK economy: '*practical engagement between schools and private industry, higher education and other STEM sectors is vital to provide young people with clear information and experience of where learning can take them'*. A lack of these types of opportunities is likely to impact on a variety of pupils including gifted and talented pupils.

13. RCUK looks to connect young people with researchers using a number of mechanisms. The RCUK Researchers in Residence scheme brings together early stage researchers, young people and teachers via exciting and innovative placements in secondary schools and colleges across the UK. Alternatively, RCUK also supports the Nuffield Science Bursaries Scheme[9], where researchers host a student within their institution. A recent report from the National Audit Office [10] shows that schools participating in these types of programmes such as Researchers in Residence and STEM Clubs see a greater increase in the number of students taking sciences at GCSE. The researchers act as positive role models for young people to expose students to exciting future study and career options and motivate students to improve grades. The demand for RCUK

[7] School Seismology Project: http://www.bgs.ac.uk/schoolSeismology/app/schoolSeismology.cfc?method=viewLatestQuake

[8] The Importance of Teaching: The Schools White Paper 2010 (Department for Education) http://www.education.gov.uk/publications/eOrderingDownload/CM-7980.pdf

[9] Nuffield Science Bursaries Scheme: http://www.nuffieldfoundation.org/science-bursaries-schools-and-colleges

[10] Department for Education: Educating the next generation of scientists (NAO report, November 2010) http://www.nao.org.uk/publications/1011/young_scientists.aspx

researchers to go into schools exceeds the number of researchers able to meet it, given the difficulties with taking pupils out of school.

14. RCUK has found that there is still a considerable demand from schools to visit their Research Centres and Institutes, although the picture is varied. For example, the Rothamsted Research, which receives strategic funding from BBSRC, has reported a dramatic decline in schools visits due to the financial and time pressures schools face. Teachers have also reported increased paperwork and administration when arranging school trips, and there have been instances of policies requiring that school trips are booked up to a year in advance. In some cases it has also been observed that the proportion of non-teaching staff accompanying pupils on trips has increased, which could impact on the quality of pupils learning experience and support if they don't have access to the specialist knowledge of their teacher.

15. Schools usually take a precautionary approach to heath and safety issues. RCUK institutes therefore have rigorous health and safety procedures in place. Some institutes are also restricted in the field trips they can host due to the hazardous nature of research conducted. For example, the BBSRC Institute of Animal Health has developed the Farm Science Visitor Centre, with separate viewing areas where the pupils can see the animals and carry out hands on activities without coming into contact with them and the associated risks such as E.Coli. The Mammalian Genetics Unit at MRC Harwell also has a bespoke schools lab that it uses to cater for schools visits, so that students can take part in a range of hands-on experiments. The schools lab has been designed to emulate a standard working laboratory however the activities offered have been designed for maximum teaching impact with minimum health and safety implications for example the laboratory only contains approved reagents and equipment. However, schools have an ongoing issue finding the funding for suitable transport, particularly in rural schools, and class supervisors for groups to carry out visits.

16. RCUK considers that it is important that the curriculum and assessment model recognises the value of these activities. As highlighted by some stakeholders through the work of the BIS Expert Group, there is concern that the curriculum could be a barrier if it is over-prescriptive. There is a risk that teachers feel constrained to prepare students for tests and exams, rather than being able to explore areas in more depth and make time for more practical work.

Research Councils UK

11 May 2011

Written evidence submitted by The Royal Institution of Great Britain (Sch Sci 22)

Background to the Royal Institution

1. The Royal Institution of Great Britain (Ri) is a scientific charity that has undertaken work in science communication and education, as well as in scientific research, for over 200 years. The Ri has written this response from its perspective as a provider of science enrichment and engagement activities for young people. The Ri has been running such out-of-school activities for many years, during which it has independently commissioned research into what motivates teachers to take their students on science visits including to the Ri and the barriers they face. The Ri also has regular and informal contact with teachers and pupils largely, but not exclusively, out of the classroom. The activity most relevant to this inquiry is perhaps the demonstration lectures for school pupils, held throughout the year at the Ri, and based on the style of the Christmas Lectures. In recent years, the Ri has also opened the L'Oréal Young Scientist Centre, which gives students the opportunity to take part in practical science activities that run for the whole day. The ethos of this centre is very much based on enquiry-led practical learning in which there is not necessarily a right or wrong answer.

How important are practical experiments and field trips in science education?

2. The Ri believes that practical experiments and science trips are vital for encouraging student interest and participation in science. Trips in particular can also give wider relevance to the work the students do in formal education.

3. In 2006 the Ri commissioned an independent study of its provision for young people. This study included an analysis of the extent to which teachers organise school science trips and the reasons why they do so. It showed that schools engage in a wide range of out-of-classroom science activities. Of the schools responding to the survey 93% had undertaken some out-of-classroom science learning in the previous year. This suggests that such activity is regarded as useful by the vast majority of teachers. Schools in London, and independent schools, generally accessed a wider range than schools in the regions and state schools.

4. This study also showed that for teachers the main impetus for engaging in out-of-classroom science activities is to motivate, enthuse or inspire pupils. Other reasons supported by more than half of teachers related to the practical uses of science and learning from someone with expert subject knowledge. Teachers considered the most important activities for pupils to be those that involved practical hands-on experience; next most important were demonstrations that could not be done in the classroom.

5. These findings support the notion that teachers value scientific field trips, and in particular those trips which involve interactions with experts, demonstrations and practical activities.

6. Looking at the Ri programmes specifically, the quote below captures the sentiments of many teachers, who organise trips to the Ri to motivate their students and give them an insight into what scientists do.

"We tend to use [Ri} events to trigger interest and enthusiasm, to show role models to encourage pupils to think about science as a career, not to teach aspects at the National Curriculum." (Secondary teacher)

7. A 2009 poll of two thousand 14-year-old students, conducted by the Ri and L'Oréal, found that despite 15% of students naming science as their favourite subject, 32% of children said they wanted lessons to be more relevant to real life and 31% to get the chance to do more of the experiments themselves. In our opinion this is due to classroom practical and demonstration too often being used as a tool to illustrate a learning objective rather than an opportunity to show the fundamental process of scientific discovery and advancement.

8. In addition, in December 2008 the primary conclusion of the SCORE report "Practical work in Science" was that 'the importance of practical work in science is widely accepted and it is acknowledged that good quality practical work promotes the engagement and interest of students as well as developing a range of skills, science knowledge and conceptual understanding'.

Are practical experiments in science lessons and science field trips in decline? If they are, what is the reason for the decline?

9. The 2006 study mentioned above also examined the reasons why teachers find it difficult to organise visits outside of schools. Unsurprisingly, these reasons centred around timetabling, cover and travel issues, as illustrated by the quotes below:

"The main factor has been shortness of lecture in relation to travel time." (Primary teacher)

"The paperwork involved at school. For a 1-hour lecture you could spend 8 hours filling in forms, writing letters, collecting money etc." (Secondary teacher)

"School procedure requires 6 weeks planning in advance." (Secondary teacher)

"Difficult to get permission to take a group of students out because of supply cover implications." (Secondary teacher)

10. Some schools are also very reluctant to take pupils on public transport:

"We currently have a policy of not using the underground (due to parental concerns after 7/7 bombings)." (Primary teacher)

11. Looking at the attendance records of the Ri programmes for young people, we observe that over the last few years, attendance of secondary schools has been in decline. From talking to a range of teachers, this seems to be because, across the curriculum, there is increased coursework being done in supervised time; therefore it's impossible to find a day when students are not being assessed in at least one of their subjects. Also informal teacher feedback suggests that the rarely cover policy means that they are finding it increasingly difficult to get cover authorised for trips out of school.

What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

12. In our experience from talking to teachers, schools' fears about health and safety policy are often worse than the reality. Current Health and Safety (H&S) legislation allows for a wide range of practical experiments to be done within schools, but the perception is that H&S concerns are the major factor in stopping the majority of 'exciting' demonstrations and experiments. This is due to a lack of confidence and experience in assessing risk, and anecdotal evidence shows us that school management teams are fearful of litigation. There is also a lack of support and experience from senior science staff to tutor younger colleagues in safe practice and the process of constructing risk assessments.

Do examination boards adequately recognise practical experiments and trips?

13. The L'Oréal Young Scientist Centre Manager at the Ri, who was previously also a successful Head of Science at a large comprehensive school, feels that current assessment schemes at both pre and post 16 do not value the practical skills that a working scientist requires. As well as experimental design and data collection it is important for students to have measurement and equipment handling skills. Presently, too much emphasis is placed upon the post experimental skills of analysis and evaluation, which, although important, are not the most stimulating for young people. Scientific discovery is an essential element currently missing from practical assessment making it hard for the student who is unlikely to follow a science based career, to see why those who do so are driven to pursue long term goals. Trips where students meet scientists at work or experience science in a creative environment can help to redress this balance but again are not valued in current assessment schemes.

If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices?

14. We feel that a key benefit of a field trip is exposure to working scientists and the awareness of a wider range of career options this experience gives them. The narrowed view of science careers that may result could easily lead to reduced motivation in science classes and students developing a lower esteem for science subjects.

    As an investigative discipline, the right balance between theory and experiment must be struck both within and outside the classroom. If high quality experiments and trips are not available this could result in teachers reverting to giving facts and answers ("Chalk and Talk"), instead of letting students explore the world through experiment without always needing to find 'the correct answer;' scientific theories are to be tried and tested not learnt. This has repercussions in the ability to teach critical and creative thinking.

What changes should be made?

15. In summary our recommendations are as follows:

- A reduction or more sympathetic structuring of continuous assessment, to allow schools windows to let students out of class.
- Examination Boards and assessment criteria should specify the amount of time a student must spend doing experimental investigative work and on subject-specific field trips.
- More support for science teachers to increase confidence in planning and delivering practical work. ASTs to concentrate on this area of the curriculum and if necessary to themselves be trained by more experienced science teachers.
- Increase understanding of health & safety legislation and its purpose within schools, and especially management. The aim of this would be to enable activities to be done safely, not forbidding them from being done.

Declarations of interest

The Royal Institution has a purpose-built laboratory space for students to take part in experimental work outside the classroom. This laboratory is partially funded by L'Oréal UK Ltd.

The Royal Institution of Great Britain

11 May 2011

Supplementary written evidence from The Royal Institution of Great Britain (Sch Sci 22a)

The Royal Institution response to the Science and Technology Select Committee inquiry into practical experiments in school science lessons and science field trips

The STEM Directories – www.stemdirectories.org

The STEM Directories are a fully searchable online resource for teachers to find out what STEM E&E activities are available in their area. They are managed by a consortium led by the Royal Institution (Ri) under a contract from the Department for Education. The other consortium members are the British Science Association and the University of the West of England at Bristol (UWE). Initially this was a three year contract. In the first year, the directories appeared in hard-copy form – one each for Science, Maths and Engineering/Technology. After the first year, feedback from teachers indicated that they would prefer a fully searchable online format.

The Directories contain information about all the national and regional STEM E&E schemes, but not those at the local level. Also, one of the criteria in setting up the Directories was that there should be a 'warm body' at the end, i.e. online resources with no human contact were not included. We are fairly certain that nearly all E&E providers are included in the Directories.

The consortium behind the Directories reported to a strategic group that comprised ACME, Score, RAEng and others. This group was chaired by STEMNET. STEMNET also had the responsibility of marketing the Directories into schools via the STEMNET contract holders. The Ri has no information about how successful the penetration into schools has been, since evaluating this part of the project was not part of the original contract between the Department and the Ri. The Ri has concerns about this penetration and would like to see more effort focused on marketing the Directories to teachers. However, this is impossible under the current contract, given the government restrictions on any marketing activity.

As part of the original three-year contract, the consortium was tasked with conducting a gap analysis, in order to identify areas of E&E activity that were missing or duplicated. This work captured feedback from teachers and providers, and was related to both to the Directories and to teachers' wider perspectives on E&E activities. It was conducted by UWE. See:
http://www.stemdirectories.org.uk/stem_scheme_providers/enrichment_&_enhancement.cfm

The strategic group was also keen to use the Directories to drive up standards in the E&E providers community by requesting that all entries have some form of evaluation. Providers were notified of this requirement last year, and this will probably be implemented later in 2011, depending on up-coming conversations with the Department.

The Ri has been given a one-year extension to the contract by the Department for Education (to end Mar 2012). This funding will enable the consortium to refresh the list of providers, but it will not cover the technical maintenance and development to change the Directories in response to further teacher feedback. This is because of government restrictions on spending budgets on any form of website. The Ri believes that the Directories are an essential resource for the science teaching community, and it would be a great pity if funding could not be found to ensure that they have an increased profile in schools, are regularly kept up-to-date and are continually developed in response to teacher feedback.

Dr Gail Cardew
Director of Science and Education
The Royal Institution

July 2011

Written evidence submitted by The Gatsby Charitable Foundation (Sch Sci 23)

About Gatsby

1 Gatsby is a Charitable Trust set up in 1967 by David Sainsbury (now Lord Sainsbury of Turville) to realise his charitable objectives. We focus our support – which in 2010/11 exceeded £68 million – on the following charitable areas:

- Plant science research
- Neuroscience research
- Science and engineering education
- Economic development in selected African countries
- Strengthening public policy
- The fabric and programming of selected arts institutions

Introduction

2 The Committee will no doubt receive considerable evidence regarding the importance of and possible barriers to practical work in school science. The Committee also has previous Select Committee reports to draw upon. We note in particular the 2006 House of Lords Science and Technology Committee report on 'Science Teaching in Schools' and the 2002 House of Commons Science and Technology Committee report on 'Science Education from 14 to 19', both of which address the issue of practical science.

3 Given the significant amount of evidence about the issues with practical work in school science, why do substantial concerns persist about its decline? Has there been an adequate response from the government and, where action has been taken, has it been successful? Perhaps most crucially, to what extent have government interventions specifically targeted practical work in school science rather than assume that general policies to support teaching and learning will somehow address the issues specific to laboratory-based science?

4 We sincerely hope that this current Inquiry – while almost certainly needing to reiterate the conclusions of previous Select Committee reports – will result in more significant and sustained action being taken to address the longstanding issues associated with practical science than has hitherto been the case. With schools facing significant constraints in the resources and support available to them, we believe there is only a small window of opportunity – perhaps the next 3 years – to put in place the necessary measures to protect the place of practical science in schools before irreversible decline occurs.

5 The Committee's Inquiry is timely therefore. Indeed, against the backdrop of Gatsby's longstanding support for practical work and concerns for its future health, we have recently embarked on a significant piece of work that, over the next 12-18 months, will seek to:

- establish an accurate picture of the current health of practical science in UK secondary schools and make international comparisons where feasible;

- unpick the current enablers and barriers to effective practical work that affect schools at a local level;

- identify the likely impact on practical work of the upcoming education policy changes, including the changes to the National Curriculum, funding mechanisms, Local Authority involvement and initial teacher education;

- make pragmatic recommendations on the action needed to ensure high-quality practical work occupies a central and sustained role in all secondary schools.

6 Practical work in Primary science education should build on the natural curiosity of children, enabling them to experience and explore the material and natural worlds. This process will continue in secondary schools, but it will be advanced by the development of discipline-specific skills and the use of specialist equipment enabling students to use a more abstract and measured approach. For brevity we refer to these as 'laboratory skills', although noting that this definition should include the skills that are developed outside of the laboratory through fieldwork.

7 In this submission we report on some of the early findings of our work. In particular we note the concerns of universities regarding the laboratory skills of first year science undergraduates and issues coming to our attention regarding the impacts of recent policy on practical work. As part of our work over the coming year we plan to explore the laboratory skills required by employers and to what degree employer needs are currently being met by science at school and college.

8 We would be pleased to share our findings with the Committee as they emerge, and to discuss how the work of Gatsby might complement the Committee's recommendations for action by other stakeholders, including the DfE.

Preparing students for success in science at university

9 In April 2011 Gatsby commissioned a small piece of research exploring the perceptions of science staff in the 15 Russell Group universities in England (excluding the LSE) regarding the standard of laboratory skills possessed by new undergraduate students. 34 respondents from 12 universities completed an online survey and 12 respondents also participated in follow-up interviews.

10 Our results can only be indicative of issues that need further investigation, but the Committee might be interested in the headline findings and quotes from respondents. These are given in the four points (a) to (d) below. We are still analysing the results

(and defining what a larger-scale study might look like) but would be willing to share the full report with the Committee on request.

(a) Across the board, respondents reported that new undergraduates lack at least some confidence in the lab (100%), and are not well equipped with lab skills (97%). Specific deficits in lab skills included manual dexterity, the ability to set up apparatus and making accurate observations.

- *“They find it difficult to diagnose and think through problems and are quick to blame equipment rather than their own technique.”*

- *“They can’t apply these tools and these skills outside the narrow environment in which they were taught.”*

(b) While 29% of our respondents reported a decline in the last 5 years in new undergraduates’ scientific *knowledge*, over half (57%) felt that the level of laboratory skills had declined in the same period. This was despite all respondents (100%) stating they had increased the grades required for entry to their courses.

- *“Although it fluctuates from year to year it is noticeable that at entry students lack confidence in the lab, and the situation is getting worse.”*

- *“With our increased entry requirements we have some excellent students with a deep understanding of concepts but our average to lower ability students struggle more now than 10 years ago.”*

(c) The largest factor contributing to the lack of lab skills was cited as students’ limited exposure to practical work at school. Respondents reported teaching students who had done very little practical work and whose teachers relied heavily on demonstrations and/or videos.

- *“Many students are telling us that they have done no practical work at school so they struggle with basic skills like using a microscope, with which they previously would have had some experience.”*

- *“Many of them claim to never have carried out an experiment only watched teacher/videos of. Most of them have no idea how to act in a lab or where to even begin when carrying out an experiment, ie no idea what equipment is called.”*

(d) University teaching staff have made a number of changes to their lab-based teaching in response to the change in skills of new undergraduates, including: simplifying first-year lab courses by providing more step-by-step instructions, removing complex experiments or allowing more time; increasing the focus and/or time spent on basic skills; increasing the levels of support through more staff time or demonstrators; and introducing online pre-labs.

- *"We have redesigned the whole first year course - removing much of the material previously taught and starting at a lower level and with much less expected in each class."*

- *"Progress through the [undergraduate] lab course is to an extent set back by the poor standard of skills among the intake. This has a knock-on effect on the types of experiments, and their complexity, that we can offer in the later years of the degree."*

11 We believe that even this small-scale survey should elicit concern regarding how well schools and colleges are preparing students for entry into science degree courses. These indications become all the more stark when one considers that: (1) the universities surveyed are taking the best A-level students (the reported entry requirements ranged from BBB to A*AAA); and (2) that all universities are increasingly operating in a more competitive environment where finances are stretched and the pressure to widen their student intake will continue.

Practical work in the National Curriculum

12 Gatsby recently submitted evidence to the government's current review of the National Curriculum in which we set out our thinking on the purposes for practical work and our recommendations for the review team. A copy of our submission is available on request; the points relevant to this Inquiry are provided below.

13 The main purposes of practical work in the curriculum are to:
- enhance the learning of science concepts and explanations;
- develop understanding of the processes of science; and
- develop laboratory skills.

14 Since the introduction of the National Curriculum there has been a steady erosion of the teaching of laboratory skills. This erosion is a cause of significant concern to industry and higher education institutions. Reversing this trend would also increase the engagement of young people in science and lead to greater participation in science post-16.

15 It is unacceptable that the assessment of laboratory skills has been reduced to the point where a GCSE student who is unable to, for example, use a microscope or heat measured volumes of liquid without breaking test tubes is still able to achieve maximum marks for their practical work as long as they can write about how they should have done it.

16 The current National Curriculum review is an opportunity to re-examine the role of practical work. In particular, the review must ensure that the Science Curriculum sets high expectations of attainment in the laboratory skills that employers and higher education value.

17 We recommend that:-

(a) The National Curriculum review team should provide an impact assessment to show explicitly how any changes to the Science Curriculum will actively encourage better practical work in schools.

(b) The Science National Curriculum should state explicitly the laboratory skills that students are expected to develop at each Key Stage.

(c) The review must ensure that the National Curriculum allows sufficient time and space for teachers to undertake a much wider range of practical activities with their students than is currently the case.

(d) The review must consider how the requirements of the National Curriculum regarding practical work at Key Stage 4 can be translated into assessment objectives across the range of science GCSEs.

(e) The review should involve higher education and employers in a much more meaningful way than has been the case in previous National Curriculum reviews. Included within these discussions should be a focus on ensuring that employer and HE requirements for laboratory skills are met, something we believe has been wholly absent from previous reviews.

Barriers to practical work – impacts of recent changes to the education system

18 As part of our new study into practical work we have begun to visit schools and talk to Awarding Organisations, Local Authority advisers and CPD providers in order to better understand the barriers to practical work and what might be done to alleviate them.

19 In our preliminary work it is clear that recent changes to the educational landscape may well have an impact on practical work and we highlight some particular areas for further investigation below. We hope the Committee will engage the DfE in discussion on these issues.

<u>Laboratories and preparation rooms</u>

20 We still hear of too many schools where practical work is limited by the amount of laboratory, preparation and storage space available, despite many of these schools going through refurbishment or being new builds. Particularly worrying are reports that some Academies have reduced the number of labs and prep areas and therefore may be compromising the quality of their science provision.

21 We would be interested to hear what plans the DfE has to ensure all schools (including Academies and Free Schools) adhere to the guidelines it itself has produced on the accommodation necessary for practical science.

School budgets and science equipment

22 The cost of some equipment and consumables associated with practical work remains prohibitive for some schools, and the number of schools and range of equipment that fall into this category are both likely to increase in the coming years as schools' budgets come under increasing pressure. A school science department must balance the costs of kit essential for practical work with the substantial demands for photocopying, stationery and textbooks.

23 The constant upheaval in the curriculum will continue to divert funds away from practical equipment towards new textbooks and work sheets; schools would benefit from a period of curriculum stability in order to focus their resources on improving their science provision.

24 While we appreciate – and support – the government's commitment to devolve to individual schools decision-making on issues such as budgeting, it will be crucial in the coming years that headteachers, senior management teams and governors are helped to understand the importance of practical science. Without government support for this – even if only in Ministerial announcements and the DfE guidance material issued alongside the new National Curriculum – it is likely that the status of practical science will continue to decline in schools.

25 Finally, some schools successful in increasing uptake of the sciences at A-Level are telling us they are likely to struggle to afford the extra equipment needed to provide these students with quality practical work. Some schools have told us that the decrease in post-16 funding for sixth forms from the Young People's Learning Agency (to bring schools into line with FE Colleges) will impact on practical provision, particularly in schools successful in motivating more students to continue with science into A-Level. More research is required to understand how widespread this effect is likely to be and we would encourage the Committee to explore this issue with its witnesses.

Teacher training and Professional Development

26 Teaching laboratory skills and undertaking practical experiments demands expertise and experience from science teachers, so it would be expected that it should form an explicit part of their training and professional development. For trainee teachers, however, it is not clear who has responsibility for this part of their training – their university or their placement schools. There is therefore a risk that it occurs in neither, or is overly dependent on the status of practical science in the trainee's school.

27 The DfE should use the review of standards for Qualified Teacher Status to clarify the expectations for science teachers to have appropriate competencies in practical work.

28 Local Authorities have traditionally played a pivotal role in networking science departments from different schools through the offices of a science consultant and/or adviser. At the height of the last government's 'National Strategies' programme this regional field force numbered around 300, but since the government decided to end the National Strategies and reduce the role for Local Authorities in school support, the number has dwindled to about 40. It is no longer clear from where schools can rely on

getting advice on practical teaching, or who will take responsibility for networking science departments so that practice can be shared.

29 The Committee may wish to ask the DfE what plans it has to ensure that schools still have access to the support and advice on practical science (including health and safety) previously freely available to schools from Local Authority advisers and consultants.

Technicians

30 It is disappointing that successive governments appear to have had so little interest in supporting the role of school science technicians, despite the potential for developing them as key staff in supporting more efficient management of purchasing and use of equipment and materials.

31 School science technicians provide essential support for practical work, particularly in schools where the department is dominated by inexperienced teachers or where staff turnover is high. And yet the pay and conditions of technicians are appalling, including a lack of real career structure, term-time only contracts and lack of support for professional development.

32 This is as true now as it was in 2002, when the House of Commons Science and Technology Committee reported:

> *"The pay and conditions under which technicians are employed strike us as downright exploitative. We can see no reason why technicians should be paid during the term time only. Those technicians who prefer not to work during the holidays, carrying out essential tasks such as equipment maintenance, should be employed on part-time contracts; others should be treated like teachers and paid an annual full-time salary. The lack of opportunities for career or pay progression needs to be addressed."* [1]

33 Nine years on, we still agree. We hope that the current Inquiry will lead to more progress in this area than has hitherto been the case.

Health and Safety

34 Concerns regarding health and safety are often used to explain a reduction in the amount of practical work undertaken in a school. We have heard a number of science teachers, even some in high-performing schools, speculate on practicals which might or might not be banned. However, there are almost no national bans on practical work in science.

35 In the past, schools have been able to consult their Local Authority science adviser/consultant or the national organisation CLEAPSS for advice and support on risk assessments and safe management of practicals. With the demise of Local Authority advisory roles (see paragraph 28), we are concerned that decisions regarding health and safety, and on which science practicals are 'allowable', may be taken by individuals who do not have the necessary experience, or access to external expertise.

[1] 'Science Education from 14 to 19' (July 2002), House of Commons Committee on Science & Technology.

36 We would encourage the Committee to ask the DfE what sustainable mechanisms the Department proposes for ensuring that all school science departments have access to correct, authoritative advice on health and safety in practical work.

Curriculum, qualifications and timetabling

37 In an effort to strengthen science education at Key Stage 4 and increase progression to post-16 sciences the government has supported increased participation in Triple Science (three separate GCSEs in physics, chemistry and biology) among 14-16 year olds. We support these moves. However we have been told that many schools have not been able to allocate Triple Science any more teaching time than ‘double science’ (2 GCSEs), and that practical work has suffered as a result.

38 If this means that students studying physics, chemistry and biology at GCSE in order to progress to A-Level sciences and beyond are gaining fewer laboratory skills, this is clearly a situation that needs rectifying. We suggest the Committee might wish to investigate how widespread this issue is when questioning witnesses and also to press the DfE on what research it has undertaken or has planned on the curriculum time schools are dedicating to Triple Science and the subsequent effect on practical work.

Science & Engineering Education Team
The Gatsby Charitable Foundation

11 May 2011

Written evidence submitted by the Assessment and Qualificatiions Alliance (AQA) (Sch Sci 24)

Declaration: The AQA is a large A-level and GCSE examinations awarding body, awarding more than 40% of full course GCSEs and A-levels nationally.

QUESTION 1 – How important are practical experiments and field trips in science education?

1. We believe that both practical work and field trips should be integral to the teaching and learning experience of our GCSE specifications (syllabuses), and of the new AQA Level 1 / Level 2 Certificates (sometimes known as iGCSEs) that we are currently developing. These hands-on activities enable students to develop a deeper and firmer understanding of science and the scientific process, which will inevitably benefit students in their examinations and better prepare them for any further scientific study.

QUESTION 4 – Do examination boards adequately recognise practical experiments and trips?

2. We do not currently include a full range of fieldwork activities in the Investigative Skills Assignments (set as a compulsory part of AQA's GCSE science examinations) in order not to disadvantage any schools or colleges that have comparatively limited resources with which to carry out fieldwork.

3. Practical experiments are encouraged within the controlled assessments of our GCSE specifications and through a focus on the scientific enquiry skills, particularly in the second paper in our AQA Level 1 / Level 2 Certificates.

4. The controlled assessment comprises 25% of the marks for each GCSE (with the exception of Additional Applied Science in which the controlled assessment is worth 60% of the available marks). Whilst, in our main science specifications, the marks for the controlled assessment are based on just one practical investigation (Additional Applied Science is slightly different), we do make it clear that teachers should carry out a wide range of practical experiments, as confirmed in the specifications for these subjects:

   > *"Teachers are encouraged to undertake a wide range of practical and investigative work, including fieldwork, with their candidates. We take the view that it is not good practice to do practical work only for the Controlled Assessment. As teachers know well, candidates enjoy and are motivated by practical work."*

5. In the AQA Certificates there is no controlled assessment; instead it is planned that practical skills will be tested in the written examination papers, especially in the second papers. In the specifications we state:

   > *"Throughout the course, candidates are expected to learn about and understand the scientific process and to carry out practical and investigative work, covering the skills of investigation design, observation, measurement, data presentation*

and handling, drawing conclusions and evaluation. These skills will be tested in both written papers, but a greater proportion of the scientific process will be tested in Paper 2."

6. We encourage the use of practical experiments to underpin candidates' understanding of the theory laid out in the substantive content of our new specifications. This is done by including numerous suggestions for practical activities. These are included to *"help candidates develop their practical enquiry skills to understand and engage with the content."*

7. In the outgoing specifications (which will cease to be taught after 2012) we annotated sections of the specification with a symbol to denote which areas identify *"parts of the content which lend themselves to extended investigative work… These parts of the content may form the contexts for Investigative Skills Assignments."* In our new specifications, we have taken this further by adding specific practical experiments and activities that teachers can use, which is a major step forward and should encourage teachers to use practical experiments more to develop candidates' understanding of science.

8. The table below shows how many practical experiments we include in our new specifications:

Specification	Number of suggested practicals
GCSE Science A	92
GCSE Additional Science	95
GCSE Biology	75
GCSE Chemistry	127
GCSE Physics	62
GCSE Science B	67
AQA Certificate in Science: Double Award	223
AQA Certificate in Biology	72
AQA Certificate in Chemistry	86
AQA Certificate in Physics	132

9. A number of these practical ideas would benefit from being incorporated into field trips. Three examples from our GCSE Biology specification are:

- investigative fieldwork involving sampling techniques and the use of quadrats and transects; which might include, on a local scale, the:
  – patterns of grass growth under trees
  – distribution of daisy and dandelion plants in a field
  – distribution of lichens or moss on trees, walls and other surfaces
  – distribution of the alga *Pleurococcus* on trees, walls and other surfaces
  – leaf size in plants growing on or climbing against walls, including height and effect of aspect
- investigating environmental conditions and organisms in a habitat such as a pond

- carrying out a survey of European banded snails.

10. In conclusion, we feel we do everything we can to recognise and encourage practical experiments and fieldwork trips in our specifications, whilst being pragmatic about the resources schools have for these activities.

Assessment and Qualifications Alliance

11 May 2011

Written evidence submitted by the British Ecological Society (Sch Sci 25)

About the BES

The British Ecological Society (BES) is a learned society with a membership comprising representatives from higher education, employers in ecological fields and others with interests in ecological science and education. The primary activity of the society is the publication of five scientific journals and scientific meetings with additional activities in policy, grant giving and education.

The society has a strong educational focus on increasing the quality of fieldwork provision within science education working directly with teachers, schools and awarding bodies in supporting fieldwork.

The BES welcomes the opportunity to submit a response to this inquiry. We have limited our focus to the decline of fieldwork in relation to ecological science and the resultant impact on field skills at higher education and beyond for the environment sector. We do however recognise that practical experiments and fieldtrips cover the full spectrum of science.

Summary

- The BES recommends that practical experiments in the laboratory and field are recognised explicitly within criteria for science curricula and assessment of science.
- Significant work needs to be undertaken on the assessment of skills and knowledge obtained through practical science to ensure that schools are encouraged to offer students a varied and comprehensive range of high quality experiences rather than a small number of predictable assessment exercises.
- Several projects have been undertaken in enabling teachers to address many of the barriers to practical experiments and fieldtrips, the BES recommends that there is a requirement for further work to be undertaken and much of this work centres around appropriate funding and support for schools, science departments and teachers.

A. The importance of field trips and practical experiments in science.

1. The BES feels strongly that high quality fieldwork, field trips and practical experiments are an essential aspect of a comprehensive science education. Familiarity and confidence in field skills, gained through personal experience of a range of natural environments, fosters a deeper understanding of the science knowledge being learned and the applications of such knowledge.

2. Fieldwork is the mechanism by which students best learn field based skills such as sampling habitats, collecting live specimens, observing live specimens in habitats, collection of variable abiotic data, risk assessment and management. Additional field/laboratory and research skills are developed through the process of identification of organisms. The majority of these skills are already identified in a number of reports[1] as skills shortages within the employment sector that will need to be addressed very soon.

3. Practical experiments and fieldtrips are often cited, by young people and many older scientists alike, as significant reasons for their decision to continue with science in higher education and employment. Such experiences promote engagement with the subject, demonstrate the breadth of the subject and particularly for those young people living in more urban environments the opportunities that might follow from further study in science.

B. Decline of fieldwork in science education

4. The decline in science fieldwork over recent years has been well documented by a number of external parties; the most recent report by the ASE outdoor science working group,[2] of which the BES is a member, summarised many of the concerns around this decline.

5. There has been a reported decrease in the overall proportion of students taking up whole organism biology courses at higher education with greater declines in areas that would traditionally have been taught most effectively through practical experiments and fieldwork, these have included plant science, taxonomy and systematics.

6. The BES can comment from direct experience that the introduction of “rarely cover rules” in 2009 had an immediate and obvious impact on uptake of the society’s fieldwork projects. Teachers and departments approached during the recruitment phase of the project citied “rarely cover rules” as the primary reason their school management teams could not allow teachers out of school to participate in training or students out of school to participate in fieldwork experiences. This however does not explain the preceding decline over the last 20 years.

7. Teacher training providers within the society are commenting that all science graduates have significantly less practical experience and confidence now than 20 years ago, with fieldwork experience being the exception rather than the norm even within the biology graduate population. Teacher training struggles to provide realistic experience of planning and managing a fieldtrip for a class of 30 students and depends greatly on existing practice within schools in which trainees can participate, this is resulting in a high number of newly qualified science teachers who have never experienced fieldtrips as students or as trainee teachers and are therefore less likely to feel confident in developing such experiences for their own students once qualified.

C. Assessment of fieldwork and specification requirements.

8. The BES has increasingly worked with awarding bodies to discuss the opportunities that fieldwork might offer assessment. We have previously encountered a perception among some awarding bodies that fieldwork infers an annual residential fieldtrip dependant on rural environments; we have also been told that assessment of field skills is unfair in light of equality and accessibility.

9. The situation is improving as awarding bodies become more open to approaching the various learned societies and subject associations for advice on what might be assessed, how this might be assessed and proposed specification content. There remain some challenges related to the number of awarding bodies and possible progression routes.

D. Implications of decline in fieldtrips and practical experiments.

10. The most common inquiry the BES receives from young people considering their undergraduate options and career paths is for advice on the best degree/route that might allow them to study animals where they live. They have very rarely been on a field trip and have a very limited understanding of the connections between working with the natural environment and the ecology in their science course. The BES is concerned that the lack of experience in practical and field settings hinders young people's awareness of the career opportunities within science and the routes by which they might be achieved.

E. Recommendations.

Dissemination of existing good practice and regional/local support.

11. Leather and Quick (2010)[3] highlight the lack of natural history knowledge among young people and the benefits of visits to urban parks in identification skills suggesting that even local fieldtrips with their limited cost implications would be an effective addition to residential fieldtrips. There have been a number of projects highlighting urban and local ecology[4] and how these can be used effectively to deliver curriculum requirements. Such projects are often small in scale and there is a need for greater dissemination of good practice and teacher support in developing such opportunities at a local level.

Explicit inclusion of practical experiments and fieldwork within national curricula programmes of study.

12. Science has a great deal to learn from Geography where there has been a less steep decline in fieldwork in the same time period. Geography has been able to maintain greater curriculum requirement for fieldtrips and it is suggested that these criteria and specification requirements have played a larger part in securing fieldwork opportunities for both trainee teachers and students.

Development of appropriate assessment making use of expert advice where suitable.

13. We would recommend that awarding bodies are encouraged to recognise that limits and challenges in assessing subject content and subject skills should not be addressed simply by removing them from the curriculum/specification. Awarding bodies should continue and build upon the recent trend to actively seek support from expert agencies in developing specification and assessment materials.

Continuous professional development for science teachers and their managers.

14. There is a persistent perception among teachers and schools that practical experiments and fieldwork are difficult to deliver and can only be achieved with high cost implications, significant time commitment and significant additional knowledge and training. The BES agrees that teachers are short on time, that the breadth of knowledge required in science is immense and that good quality science provision does bring with it additional costs however the BES has also worked with schools in challenging circumstances to show how these issues can be addressed, often more easily than might be expected when schools are sufficiently supported. The primary requirement is always that the senior management team and departmental leaders within a school appreciate and value the role of practical science, encouraging an ethos of science as a practical, explorative and investigative discipline.

1. E.g ERFF report 7 (2010): Ten most wanted, Post graduate skills for the environment sector.
2. Outdoor Science, A co-ordinated approach to high quality teaching and learning in fieldwork for science education.
3. Leather and Quick (2010): Do shifting baselines in natural history threaten the environment. The environmentalist Editorial.
4. E.g London Outdoor Science project, BES school grounds project.

British Ecological Society

11 May 2011

Written evidence submitted by CLEAPSS (Sch Sci 26)

About CLEAPSS

Founded in 1965, CLEAPSS has promoted effective practical science in schools for over 40 years.

CLEAPSS currently has 13 staff consisting of 8 advisers and 5 support staff.

At its core CLEAPSS is a Consortium of all the Local Education Authorities in England, Wales and Northern Ireland. At present all maintained primary and secondary schools are members of CLEAPSS as are many independent schools, a significant number of colleges and many overseas schools.

CLEAPSS is funded by subscription from Local Authorities (on behalf of their schools) as well as subscriptions directly from individual schools/colleges in other categories. CLEAPSS is independent of any other commercial or non-commercial organisation and as such its advice and guidance is completely impartial.

CLEAPSS provides model risk assessments (MRAs) for practical activities in science, Design & Technology and Art & Design for both primary and secondary phases. Membership of CLEAPSS enables an employer to discharge its duties under the 1975 H&S at Work Act in respect of these subject areas.

In addition to H&S guidance CLEAPSS provides advice on ways to carry out practical activities so that they work, are safe and are effective at supporting learning. CLEAPSS has facilities at its offices on the campus of Brunel University in Uxbridge to enable it to test equipment and try out new ideas for practical work. As a result CLEAPSS staff have developed a wealth of experience devising and evaluating practical activities.

CLEAPSS advice and guidance, contained in publications such as *Hazcards* and the *Recipe book*, is recognised by Ofsted and the HSE as the definitive basis for safe practice for practical work in schools.

"The Committee has noted press reports that the number of practical experiments in science lessons in schools and science field trips may be in decline"

Response

1. How important are practical experiments and field trips in science education?

a. Effective practical work is critical for developing pupils' ability to think scientifically and with this to develop their understanding of how science and scientists have arrived at what we currently understand about the world.

b. Scientific theories are developed and tested through rigorous analysis of reliable and accurate evidence. Pupils need to be able to recognise accurate, reliable evidence and know how to collect it. Practical work gives pupils the experience of collecting evidence about the behaviour of the real world.

c. Practical work can be used to support a wide range of learning outcomes for pupils – possibly more than any other individual teaching and learning strategy – the SCORE project “Getting practical” (www.getting practical.org.uk) explores ways to ensure teachers maximise the impact of practical work on pupils’ learning by ensuring clear learning outcomes are identified for each activity.

d. The UK government clearly recognises the strategic and economic importance of upcoming generations developing high level skills in the sciences, engineering and mathematics. A good supply of young people with science, technology, engineering and maths (STEM) skills is important to promote innovation, exploit new technologies, produce world-class scientists and for the UK to compete internationally.

e. The 2008 SCORE report on practical science in schools in the UK noted as a key finding that the importance of practical work in science is widely accepted and it is acknowledged that good quality practical work promotes the engagement and interest of students as well as developing a wide range of skills, science knowledge and conceptual understanding. In the words of one teacher “science without practical work is like swimming without water”.

f. More recently (April 14th 2011), in its response to the Department for Education’s Call for Evidence regarding the National Curriculum Review, SCORE stressed the importance of fostering scientific thinking and encouragement of laboratory work. SCORE emphasises that ‘essential knowledge’ in the sciences includes ... the acquisition of procedural skills (particularly those associated with practical laboratory and field work, and analysis), as these are essential for acquiring and testing scientific knowledge.

2. Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

Evidence from enquires by schools and colleges to the CLEAPSS Helpline suggests that practical activities are in decline in some, though not all schools. Some of the reasons are outlined below.

a. A lack of confidence on the part of teachers and technicians arising from:-

    I. H&S considerations. These are a contributory factor but CLEAPSS does not believe that H&S issues alone are responsible for declining confidence to carry out practical work with pupils (see section 3)

II. Pupil behaviour – Poor pupil behaviour is often cited as preventing practical work. Teachers do not always acknowledge the relationship between good teaching and learning (including effective practical work) and pupil behaviour. As a result many become caught in a cold war type stand-off where the teacher won't do the practical because the pupils won't behave but the pupils won't behave because they are not allowed do the practical work.

III. Lack of familiarity with practical activities, particularly amongst younger teachers – this is a vicious circle – many young teachers experienced less practical work when they themselves studied science in school – they have no first had experience of many of the practical activities that those from an older generation regard as entitlement experiences for pupils learning about the world around them.

IV. Experiments that appear not to work. Limited staff/technician expertise can mean that experiments don't work. Teachers lose confidence in practical work and may use computer simulations, or book work, as a substitute. This is evident from the helpline enquires we receive.

b. Limited access to subject specific CPD - Teachers do not (or are not allowed by senior managers) to attend CPD that would improve their use of practical work, despite there being plenty of opportunities on offer from CLEAPSS and other organisation such as Science Learning Centres, learned societies etc. As a result the majority of CLEAPSS CPD is delivered to technicians who then have the unenviable task of convincing teachers to adopt the ideas. CLEAPSS courses specifically for teachers often fail to recruit because:-

I. Funding – often quoted as a reason for not releasing teachers on CPD. CLEAPSS believes that it is a more question of priorities than of absolute funding.

II. An inflexible interpretation of the 'Rarely Cover' agreement makes it difficult for teachers in many schools to attend CPD.

III. Excessive focus on short term improvements in pupil outcomes mean that those in schools deciding on CPD priorities rate subject specific CPD lower than generic teaching and learning training.

c. Insufficient technical support - Effective, meaningful practical work is difficult to realise in schools without adequate support from specialist, knowledgeable technicians. In the present climate technician numbers are being reduced.

d. Loss of specialism – Many secondary schools no longer have a balance of science teachers across the science specialisms, for example many science departments in London do not have any physics specialists at all. Teachers, teaching outside their specialisms, need to be supported by an appropriately qualified colleague. The lack of such support has a particular impact on practical work as although it may be possible to 'mug up' on the theory it is much more difficult to develop the repertoire of techniques needed to support a rich variety of practical experiences.

e. Teachers have limited opportunities to develop or rehearse practical work. High contact ratios and high lab occupancy rates along with other duties reduce the time available for this essential aspect of developing confidence.

f. Time constraints. Practical work in many areas of modern biology (microbiology and gene technology in particular) is too complex to be carried out in one lesson. A current move to 50 minutes lessons in many schools is likely to exacerbate this problem. Preparing the equipment can also be time consuming. Equipment costs are high.

g. Reduced priority for science in years 5 & 6 as a consequence of the removal of the statutory end of key stage tests in science.

h. An over reliance on uninspiring and poorly researched published schemes. These often contain practical activities that have been re-hashed may times over and feature vague instructions that lead to practical sessions that don't work or in some cases can even be dangerous. (linked to time constraints above and to lack of teacher confidence). The changing nature of the teaching profession means that many teachers no longer see developing new activities (practical or otherwise) as part of their job – they have become deliverers of someone else's ideas.

i. Limited focus on practical work in Initial Teacher Training (ITT). The time given to developing this aspect varies dramatically across the ITT sector. As an indicator of this, the time spent introducing student teachers to CLEAPSS resources varies between ITT courses from no mention of it at all to a full day of hands on experience using CLEAPSS resources to risk assess practical activities.

j. Unsuitable accommodation. Despite good advice contained in Building Bulletin 80, Science Accommodation in Secondary Schools, published by the Dept for Education and amplified by CLEAPSS, the design of science teaching spaces in new buildings is frequently poor. Problems reported to CLEAPSS include, inadequate size of rooms, unhelpful layout of the science suite, lab designs which do not lend themselves to class practical work and reduction, from the traditional calculation, in the total number of labs provided. For instance, the rooms may have the gas supply and electrical sockets on the outside wall so that pupils have their back to the teacher or the rooms may have only one or two sinks

3. What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

a. Teachers and technicians often cite health and safety law as a deterrent to practical work. This is misguided. The HSE want pupils to experience the handling of chemicals, aspects of hygiene when dealing with microorganisms and be shown how radioactive materials can be manipulated safely.

b. School science is in reality very safe. Teachers and technicians are however worried about litigation and schools are concerned about insurance claims in case something goes wrong. CLEAPSS is aware that in reality events of this kind are very, very rare and are even if they do occur they are very unlikely to result in a prosecution or civil case against an individual teacher or technician.

c. CLEAPSS believes that by adopting the 'common sense' approach to risk assessment it promotes H&S should not represent and unmanageable burden for teachers or technicians and as such should not prevent exciting and effective practical work from taking place in schools. Under various Regulations (e.g. COSHH, The Management of Health and Safety at Work, and others) the employer is required to undertake a risk assessment for activities done and materials used as part of the practical work. An employer may provide model (or generic) risk assessments. In science and D&T, the vast majority of school and college employers in England, Wales and Northern Ireland provide the model risk assessments produced by CLEAPSS (SSERC in Scotland). Before undertaking an activity as part of a lesson, a teacher must consult relevant model risk assessment(s) and should adjust or adapt the outcomes of the model risk assessment to meet the needs of their individual circumstances. The significant findings of any risk assessment procedure are best recorded on documents in daily use, such as a scheme of work, lesson plans, worksheets or technician's notes.

d. Myths abound. A survey in 2005 found that of 40 chemicals or activities thought by callers to the CLEAPSS Helpline to be banned; only two were actually banned nationally.

e. Impact of recent European legislation, Classification, Labelling and Packaging of Substances and Mixtures (CLP) and Registration, Evaluation, Authorisation & restriction of CHemicals (REACH)

    I. The CLP legislation is indicating additional hazards on a number of chemicals even though in reality the substance has not changed at all – this increases the perceived risk (for example, petroleum jelly is now labelled as a class 1B carcinogen). CLEAPSS is receiving many enquiries from teachers and technicians worried about a perceived greater risk.

    II. REACH –The shift of emphasis to the identification of *hazard* as opposed to *risk* (the latter factors in the level of exposure) has already lead Ireland to issue a blanket ban on the use of chemicals identified as "substances of very high concern" (SVHC) in schools. As well as removing certain activities from the schools' curriculum at a stroke CLEAPSS believes this is unnecessarily alarmist and works against a common sense, proportionate, response to risk assessment.

f. H&S can become a barrier to effective practical work in certain circumstances:-

    I. Where schools or colleges engage agencies from outside education to carry out H&S audits. In these circumstances CLEAPSS finds that H&S 'inspectors/advisers' in question have little experience of how practical work operates in schools and attempt to apply regulations in a manner more suited to an industrial or commercial context. One of the strengths of CLEAPSS guidance is that it interprets regulations in a manner that makes sense in a school or college context.

    II. Where there is an excessive focus on the product of the risk assessment process – for example attempting to record and store detailed risk assessments for every practical activity. Filing cabinets full of dusty forms do not contribute to safe practice in the classroom.

4. Do examination boards adequately recognise practical experiments and trips?

a. CLEAPSS believes that in general the models for assessed practical work, in particular the enquiry based activities, implemented by awarding bodies at GCSE restrict the range of practical work done in schools.

b. CLEAPSS is involved in advising awarding bodies on the practical component of their assessments. CLEAPSS believes however that its involvement is often at too late a stage in the development process. Over 400 calls to the CLEAPSS Helpline over the last 18 months mentioned the word 'assess' or 'assessed' and involved problems with assessment activities provided by awarding bodies. Further calls involved activities similar to those known to be used in assessments. Had CLEAPSS been consulted before the activities were published, most of the queries would not have arisen.

c. Many of the current models of assessing practical skills are so tightly restrictive that many teachers feel they have inadequate time to make proper use of the full range of practical activities that would support good science teaching and learning. Teachers feel obliged to follow particular approaches in order to enable their students to recognise the format of examination questions/assessment items. Pressure from the assessment model can reduce practical work to a formulaic activity akin to jumping through hoops.

d. Many of the activities on which assessments are based are dated in their approach. As a consequence they can require large amounts of materials which can in turn cause disposal difficulties for technicians as well as having significant cost implications for schools.

e. CLEAPSS suspects that many assessment activities are devised on the basis of a vague memory of an activity and are not trialled sufficiently before being adopted as formal assessments.

f. CLEAPSS has found that often insufficient research goes into the availability and costs of the resources used in the activities. Educational science suppliers require advanced warning in order to amass the required stocks of chemicals, microorganisms, enzymes and equipment to satisfy the requirements of thousands of candidates.

5. If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

a. Pupil's choices at post-16 are very closely linked to the subjects they enjoyed at GCSE level. When interviewed about science pupils invariable identify the practical work as the aspect of science they enjoy the most and the one that most helps them learn. Any reduction in practical activity and fieldwork is likely to have a negative impact on recruitment to post 16 sciences.

b. The employment, FE and HE sectors often comment that students have fewer skills when they arrive now than they had in the past. This can mean that extra tuition, supervision or training is required.

c. Hazardous materials are encountered in the home, at work, in the garden and certain hobbies. The consequence of mishandling or ingesting these chemicals results in visits to the doctors' surgeries and Accident & Emergency centres. Information collated by RoSPA indicate that at least 9,000 injuries involving a range of hazardous chemicals were recorded per year (data from 2000 -2002, the latest available in their online HASS and LASS database[1]) It is important that schools teach children the life skill of handling hazardous material safely and with respect.

d. Practical activities in science are an obvious vehicle to teach pupils about risk – developing a sensible approach to evaluating risk is an important life skill for everyone.

6. What changes should be made?

a. School technicians deserve greater recognition, a clearly identified career structure and guaranteed access to high quality on-going professional development are needed

b. CPD in effective practical work for teachers should be viewed with the same level of importance by senior management as courses which are more obviously aimed at improving examination results. (Ironically more effective use of practical work would improve learning and bring about the very improvements in pupil outcomes that schools seek)

RoSPA Home and Leisure Accident Surveillance System (LASS and HASS), based on data from the then DTI for the UK. This data is no longer being collected. http://www.hassandlass.org.uk/query/MainSelector.aspx

c. Greater coordination of activities designed to promote the importance of practical science – for example through an extension of the “Getting Practical” programme to act as a focal point for promotional activities.

d. Easily accessible resource bank(s) containing detailed instructions of how to carry out a wide range of common science practical activities. Teachers could source reliable/safe practical activities, deciding what the learning outcomes are for their particular lesson. Awarding bodies and publishers could access a range of activities that worked and were safe to include in curriculum materials and assessment items.

e. A high profile information campaign backed by the HSE (supported by CLEAPSS and SSERC) to ensure that schools and colleges respond appropriately to the changes to chemical labelling associated with CLP and REACH regulation and do not unnecessarily reduce practical activity.

f. CLEAPSS believes that there is considerable scope to adopt reduced or micro-scale approaches to practical work in schools. Advantages include, reduced hazards leading to greater access for pupils to activities, better model for the techniques used in the ‘real world’, reduced cost and easier disposal with less environmental impact. These techniques are in use widely around the world but are virtually absent from schools in the UK. There should be a concerted effort to promote this approach – for example by including reduced/micro-scale activities as part of formal assessments.

7. Is the experience of schools in England in line with schools in the devolved administrations and other countries?

a. CLEAPSS often receives enquiries from teachers, technicians and curriculum developers/publishers in other countries (both in Europe and further afield) requesting permission to use its resources – particularly in relation to risk assessments. From these conversations CLEAPSS is strongly of the opinion that support for and hence practice in practical work – particularly that carried out by pupils – is less well developed elsewhere than it is in the UK.

b. The United Kingdom has an enviable tradition of practically based teaching in science. There is a risk that practical work in science could be taken for granted (ubiquitous, invisible in plain sight) and as such will not receive the support/development necessary to retain its central role

Steve Jones
Director
CLEAPSS

11 May 2011

Supplementary written evidence submitted by CLEAPSS (Sch Sci 26a)

This paper provides additional evidence relating to technician hours, technicians role in supporting practical work in schools and the potential for reduced or micro-scale approaches to make a significant contribution to practical science in schools.

Technicians

A comprehensive guide to the crucial role played by technicians in school science can be found in CLEAPSS Guide G228 *Technicians and their jobs* a copy of which is attached to this additional submission.[1]

This guide draws on the findings of a national survey of science technicians conducted in 2001 by the Royal Society and the Association for Science Education.

The RS/ASE report recommended that:

- there should be a national framework for technicians' pay and job descriptions;
- a common formula should be adopted to determine the number of technician hours that schools need;
- technician training should be properly funded;
- there should be a nationally-recognised induction programme;
- there should be a recognised career structure;
- heads of science and governors should look at the way technicians are managed.

How many technicians are needed?

The RS/ASE report proposed a common formula for calculating the number of technician hours needed

Technician hours per week needed = total science teaching hours × 0.85.

The figure of 0.85 is known as the **service factor**. This figure was recommended by the ASE to ensure adequate technical support for the science curriculum. The ASE also stated the quality of the technician support that could be expected for different service factors.

Service factor	Quality of technician support
0.85	This is the recommended allocation of technician support to science teaching for a compact suite of laboratories with adjoining preparation and storage space. All functions are feasible, including access to training and the development of opportunities to meet a school's changing needs.
0.75	At this level of allocation, provision of the full range of functions will depend upon recruiting well-qualified and experienced technicians. Where the full range is possible there will be a need to prioritise functions and decide on the emphasis of support required. It may still be possible to achieve a balance between resource-related, design & development and direct support activities.
0.60	It will not be possible to deliver all functions adequately and a restricted range of priorities will need to be identified. Efficient management of resources and administration are likely to be affected and activities related to the design & development of practical programmes and direct support will be in jeopardy. Functions possible may well depend on the skills and experience available and a policy for training will be essential if an effective service is to be maintained.
0.45	Functions will be markedly reduced and in most cases no more than simple, immediate, maintenance and control will be possible. In the long term, efficiency in these will be impaired.

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[1] Not printed here

	The availability and range of resources will become restricted and the development of effective practical programmes is likely to be impaired. A supervisory structure for the less experienced may have to be provided from elsewhere. Regular training will be essential but difficult to provide.

It should be noted that these factors are based on a 52 week working year and not a term time only pattern of working.

Although no comprehensive survey has been completed since, CLEAPSS believes that technician working hours have steadily decreased over the past 10 years with the majority of secondary schools struggling to achieve the lowest service factor. In addition term time only working has become more common place and very recently there has been an increase in calls to the CLEAPSS helpline from technicians working in schools where a further reduction in working hours in being proposed. It would appear that the link between the sufficiency of technician support, the quality of practical activity and ultimately the outcomes for pupils is still not widely appreciated.

Technicians as champions for effective practical work – an opportunity

This idea was raised in one of the oral evidence sessions where CLEAPSS was not present.

CLEAPSS believes that there is significant potential for technicians to work alongside teachers in co-deigning the practical component of learning in science. Teachers determine the learning intended for pupils and are ultimately responsible for designing the lesson however in many cases experienced technicians can offer a valuable insight into suitable practical activities to support pupils learning.

In the current climate it is difficult for teachers to be released from teaching to attend CPD focusing on developing practical expertise. With no cover implications it is easier for technicians to access CPD in school time – this is reflected in the take up of CLEAPSS CPD where the ratio of technician training days to teacher training days is roughly 3 to 1.

At around £85.00 per day CLEAPSS training is very cost effective. It is designed to allow technicians to learn not just safe and effective ways to set up and clear away practical tasks but also to experience what the pupils actually do in the activities. This puts the technician in a strong position to support teachers. CLEAPSS has adopted this strategy as a pragmatic response to the increasing difficulty of accessing teachers directly through CPD.

Discussions with technicians attending CLEAPSS CPD sessions (in excess of 1000 technicians attend CLEAPSS CPD each year) suggest that in some schools technicians already support teachers with the design of practical activities but that where this occurs it is opportunistic rather than planned. Whereas a technician might, for example, be called upon by a newly qualified teacher to help select and adapt a practical activity to suit a particular lesson they are much less likely to be able to persuade a more experienced teacher to try out a new technique that they have come across through a CPD opportunity or a technician network. In many science departments the technician’s expertise with practical activities is under-valued by teachers in CLEAPSS’ opinion this is profoundly unhelpful, leading to resentment on the part of technicians and missed opportunities for improved practical learning opportunities for pupils.

CLEAPSS has recently piloted a 12 day CPD programme for new science technicians. One of the aims of this programme is to increase the technician’s confidence and encourage then to see themselves as partners with teachers when it comes to devising practical activities. Initial feedback from the participants and their schools has been very encouraging.

Reduced and micro-scale approaches to practical work

In essence reduced and micro-scale approaches are about using smaller quantities of materials in practical activities. The smaller quantities necessitate different practical techniques and different apparatus.

CLEAPSS believes that reduced and micro-scale approaches have an important part to play in the future of practical work in science education.

The use of reduced or micro-scale approaches to science is common countries in the far-east, middle-east, Africa and parts of Europe, both in science education but also in research and commercial fields. The driver for the adoption of these approaches varies between contexts but includes a lack of specialist laboratory accommodation, difficulties in obtaining apparatus and reagents and tight controls over disposal of waste into the environment.

In UK education reduced and micro-scale approaches are currently uncommon. It has been observed, that in school chemistry, for example, the standard apparatus has not changed at all in the last 100 years, to put it simply, chemistry teachers in the UK are still predominantly 'bucket chemists'. In contrast science technicians are overwhelmingly positive about the micro-scale approaches they are introduced to on CLEAPSS courses but invariable go on to bemoan their lack of influence over teachers practice in the classroom.

Common objections to the use of reduced or micro-scale approaches from teachers in schools in the UK

- The equipment and methods are not in our text books.
- Exam boards do not use these approaches in practical examinations.
- It's not what I expect with chemical equipment; there is no Bunsen burner in many of the experiments.
- Too small and fiddly for me and my pupils to use (mostly from teachers of boys).
- It is not spectacular enough to hold the attention of my pupils

In contrast to the above list CLEAPSS' experience of working on micro-scale approaches suggests the following

- It allows a once dangerous experiment to be carried out more safely, sometimes as a class practical rather than a demonstration.
- It shortens the time taken to complete practical activities so lessons are less rushed.
- It will, in the long run, reduce the cost of equipment and of consumable materials.
- It enables the teacher to have a firmer teaching relationship and better class control
- It enables the user to obtain stunning visible effects when filmed or projected onto a whiteboard.
- It reduces technician time in disposal and clearing up.
- It reduces waste, a factor that is becoming important in the UK
- It can show equivalent, or in some cases better, quantitative results

Examples of effective, low cost, reduced scale chemistry activities can be seen on the CLEAPSS YouTube Channel http://www.youtube.com/user/CLEAPSS

Steve Jones (Director)
CLEAPSS

July 2011

Written evidence submitted by the National Union of Teachers (Sch Sci 27)

1. The National Union of Teachers (NUT) is the largest teachers union representing teachers and head teachers at all key stages across England and Wales. To inform its submission the NUT invited comments to the questions posed by the Select Committee from science teachers and health and safety representatives.

How important are practical experiments and field trips in science education?

2. Practical work is crucial to the teaching of science. Science is after all a practical discipline and proceeds by practical tests of hypotheses. Science teachers consulted by the NUT feel that there is not as much practical work being undertaken in schools as they would like and there are a number of reasons for this. New teachers will encounter practical science work within schools' schemes of work and due to time pressures and needs, may not be tempted to look outside these schemes. The overall result is that many new teachers, in particular, may not feel confident in planning, teaching and following up practical and field based science lessons. The end result is a narrowing of the scope of practical work and class demonstrations. Teacher training should allow trainees time to experiment with a wide range of practical work, and science teachers should have a range of high quality opportunities as part of their continuing professional development to reinforce their ability to teach science through investigative, and enquiry based, science practical lessons and work in the field.

3. In addition to being invaluable to science teaching and learning, field trips have clear cross-curricular benefits particularly in relation to personal, social and health education (PSHE).

Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

4. The overloaded and over-prescribed nature of the National Curriculum, especially in primary schools, means that the scope for the open-ended practical is much reduced. Scientists frequently spend a long time on practical tests only to come to the conclusion that the theory was wrong in the first place, but they learn a lot on the way. New teachers will have studied at university using modern techniques and equipment which will not be available or relevant in school. This means that their previous experience, university education and training all contribute to restricting the practical work that new teachers feel confident in undertaking in school. Learning objectives, level statements and pressure to push the

student to achieve centrally imposed targets based on narrow definitions of pupil attainment all contribute to narrowing the scope of practical work. This leads teachers to do one experiment that shows the general trend and to fill in the detail as a straightforward theory lesson. Such practice lends itself to the prescribed method of teaching in that the three stages are easily identifiable and can be easily observed by Ofsted or school management.

5. Although a new teacher may be a highly qualified Biologist, for example, he/she may not have the skills and background to teach chemistry or physics with the necessary enthusiasm and expertise. This again highlights a shortfall in teacher training and courses are needed in the basic skills of setting up equipment, demonstrating, researching and carrying out practical work outside the narrow confines of the scheme of work.

6. In summary, teacher training is inadequate and rushed. The constricted National Curriculum, pressure to achieve targets and to move onto the next, leaving little time to consider issues around a topic and the insistence on a narrow one size fits all, rigid and boring method of teaching, have all conspired together to narrow the range of, and opportunity for, good class practical work. Teachers also need access to high quality professional development opportunities throughout their career in order to develop their expertise of lessons based on practical science and field work. Such professional development opportunities should be identified by teachers themselves rather than imposed upon them.

7. Field trips are a very useful adjunct to science teaching adding breadth, depth and relevance to what is taught in science lessons. However, to undertake a field trip involves a large amount of paperwork in terms of risk assessment plus a great deal of work for the organising staff. These staff will already be under pressure in terms of time and to achieve targets.

8. Inevitably a well organised field trip will take a number of staff out of school for at least a day. This has knock on effects in terms of extra workload for staff not going on the trip and possible financial ramifications in terms of payments for supply staff. Again the pressure to achieve national curriculum targets means that if the targets can be achieved without the hassle of a field trip why bother? The fact that education in its widest sense implies an opening of the mind, stimulating thought and enquiry, something encouraged by, for example, a visit to the Science Museum, seems to be ignored by Ministers who seem to see education solely in terms of examinations passed or national curriculum targets achieved. The effect of a good field trip cannot be measured in terms of targets achieved.

9. In recent years for many schools and pupils, the opportunities to participate in science field trips and other activities outside the classroom are perceived as prohibitively expensive. If insurance premiums continue to rise as a result of the real or perceived fear of litigation, then outdoor

education centres will be less likely to be able to subsidise the cost of places and schools will be even more reluctant to participate in activities outside the classroom. The cost effectiveness of school visits is a particular issue for small rural primary and secondary schools who may also be faced with increased transport costs.

10. As the Select Committee on Education and Skills noted in their 2005 Report "the provision of activity centres and other facilities is closely linked to the way in which outdoor education, and education more generally, is funded." (paragraph 64[1]) Centrally held budgets were increasingly under pressure, even then, as more funding was delegated to schools. The current cuts to local authority budgets are very likely to have a severely detrimental impact on school activity centres and transport provision.

What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

11. Health and safety considerations are important where practical work is concerned. An experienced teacher will run practical work because he/she has done so before many times and knows what the risks are. According to one Primary Head teacher children too can benefit from *"an emphasis on health and safety responsibilities of all concerned."* These "*enhance the self sufficiency and PSHE experiences for the children and are a key factor in taking them on this kind of experience."*

12. Health and safety regulations, insofar as their application to school practical work is concerned, are not always well understood by teachers, or local authority safety advisers whose background may be industrial.

13. It is felt that there is a distinct lack of guidance from the Health and Safety Executive who do not appreciate the circumstances in which science teachers work and guidance produced by CLEAPSS[2] often tends to encourage the production of unnecessarily complex risk assessments. As a result the risk assessments produced range from the ridiculously complex to none at all. Some science departments call for risk assessments that would frighten new teachers away from even trying new practical work while other science departments rely on risk assessments produced by commercial scheme authors that are largely irrelevant to the situation in which teachers may find themselves. Such "Out of the Classroom" guidance is viewed by teachers as taking priority over any decision to carry out experiments or run a field trip. In addition teachers are also put off by local authorities insisting on adherence to their policies and protocols to the letter.

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[1] http://www.publications.parliament.uk/pa/cm200405/cmselect/cmeduski/120/12006.htm

[2] CLEAPSS is an advisory service providing support in science and technology for a consortium of local authorities and their schools including establishments for pupils with special needs.

Do examination boards adequately recognise practical experiments and trips?

14. In response to this question science teachers consulted by the NUT responded *"No and they never have done".* There is a feeling that exam boards *"are only interested in getting the content of their course assessed from a theoretical point of view that can be validated by either computer marking or by moderated exam scripts"*.

15. It is important to recognise, however, that awarding bodies operate within the constraints of a regulatory framework for qualifications, and that the design of that framework can be politically motivated. An example is the variety of changes over the years related to maximum and minimum amounts of a qualification which can or should be assessed through coursework, and the eventual removal of coursework at GCSE entirely in favour of 'controlled assessments'. It is through flexible assessment methodologies such as coursework that good quality investigative science, based on practical work and work in the field, is facilitated, and by which students are encouraged to become the more independent and inquisitive learners that a science education should particularly lend itself to.

16. All teachers need to be enabled to acquire and develop their skills as an assessor, including in relation to practical and field based science. It is important to recognise that are aspects of science, as with other subjects, which contribute to a richer and fuller development of knowledge, skills and understanding of science but which may not be easily and readily assessed through the traditional constraints of examination based qualifications.

If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in higher education?

17. There is a danger that the lack of practical experience will mean that mainly theoretical scientists leave school and who then face increased difficulties in their Higher Education course choices many of which are more practically based than GCSE and A Level courses. Consequently, we are not producing enough technically minded scientists. In the words of one science teacher: *"We need more technicians in industry and less Stephen Hawkings. Maybe it is no surprise that the number of students attending HE science courses is declining and the number of those achieving certain grades is falling?"*. It is noteworthy, however, that some gains have been made recently in enhancing the uptake of separate science subjects at GCSE, and some increases in enrolment of science subjects at A level also.

18. It is vital that a range of options continue to be made available in order to meet the needs, aptitudes and aspirations of different learners. For some learners, scientific 'literacy' to meet the demands of the 21st Century are

sufficient. For other learners, it is vital that there are clear progression routes to study at advanced level and in higher education, and/or that scientific education provides a solid foundation to work in specific industries with a strong scientific focus.

19. In developing such learning routes, however, it is paramount that no young person is prevented in the future for progressing to the next level of scientific education should they wish to do so.

What changes should be made?

20. We have to decide whether we want to educate our children or simply to push them through pressured, restrictive, sometimes boring, target led experiences. Education involves understanding and interest, not just the ability to regurgitate facts.

21. Teacher training and professional development for science teachers needs to be re-examined, as does the process of risk assessment. Risk assessments need to be simple and relevant. Schools need simple guidance on how and what to risk assess.

22. GCSE and A Level exam courses need to be developed in such a way that appropriate time can be devoted to experiments and field trips which enhance and consolidate the learning that takes place. The assessment process should include a significant amount of work related to such experiments/field trips that can be marked and moderated by those who actually teach the course (and for which they are appropriately recompensed).

23. It is vital that children and young people from lower-income families, or those facing increasing financial uncertainty, are not excluded from taking part in practical lessons or field trips because the costs involved are prohibitive. Schools are increasingly more sensitive to the needs of children who live in low income households to ensure that they are not stigmatized nor socially excluded from school activities. It is also hoped that despite squeezed budgets the Government will give serious consideration to how it will structure funding to ensure all children can access practical and outdoor learning experiences.

National Union of Teachers

11 May 2011

Written evidence submitted by The Geological Society of London (Sch Sci 28)

1. The Geological Society is the national learned and professional body for Earth sciences, with 10,000 Fellows (members) worldwide. The Fellowship encompasses those working in industry, academia and government, with a wide range of perspectives and views on policy-relevant science, and the Society is a leading communicator of this science to government bodies and other non-technical audiences. This submission has been prepared principally by our Education Committee, which in addition to academic geoscientists includes school teachers and representatives from industry.

How important are practical experiments and field trips in science education?

2. An essential element of training in any scientific field is to learn to plan, conduct and evaluate an experiment, and it is important to nurture these abilities from an early stage. In Earth science, particular skills that need to be developed are observation, recording, creating a hypothesis, and testing that hypothesis against further observation. Much of the skill of a modern Earth scientist lies in being able to deduce a 3-dimensional structure from 2-dimensional observations that are made at the surface. Field trips are an essential part of developing these skills, and of acquiring a basic familiarity with rocks and their properties as they occur in the environment. The revised Quality Assurance Agency (QAA) benchmark statement for Earth sciences, environmental sciences and environmental studies (or 'ES3') (QAA, 2007) states that 'it is impossible for students to develop a satisfactory understanding of ES3 without a significant exposure to field-based learning and teaching, and the related assessment'.

3. In their guide to effective fieldwork in environmental and natural sciences, Maskell and Stokes (2009) reviewed evidence for the importance of fieldwork. Kern and Carpenter (1984) found that Earth science students who learned in the field are more motivated, have more positive attitudes, and place more value in their work than those that learn in the classroom. A second study by these authors in 1986 found that students learning through fieldwork performed better in tests which required them to apply more sophisticated (higher-order) cognitive skills, including analysis and evaluation. Mackenzie and White (1982) reported that fieldwork helps create 'memorable episodes' which form the basis for long-term 'deep' learning. The findings of Nundy's (1999) study of primary school children undertaking physical geography residential fieldwork supported those of both Kern and Carpenter, and Mackenzie and White. Nundy also suggested that both emotional (affective) responses to fieldwork and the associated cognitive development are important aspects of the learning process, rather than simple independent outcomes. Interestingly, Nundy identified that the types of events that children were most likely to remember were those involving an element of 'fun' – those which were enjoyable and made them feel good. More recently, Boyle et al. (2007) showed that students' attitudes and motivation improve as a result of participating in

fieldwork, whilst Elkins and Elkins (2007) demonstrated increased conceptual gain in students learning entirely in the field against those learning in more passive environments. These studies all support the widely held notion that fieldwork helps students to improve their learning by developing their thinking or cognitive skills, and that aspects of the field experience relating to enjoyment and motivation are an important part of that learning process. Where fieldwork is structured around problem based learning, Perkins et al. (2001) noted that students are much more engaged; more are prepared to take on responsibility and control their own learning.

4. While we are largely concerned with developing skills that are pertinent to the Earth sciences, we recognise the importance of practical experiments and fieldwork within all the sciences as a vital element of developing high level cognitive and practical scientific skills.

Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

5. In our opinion, there is widespread decline in opportunities to expose learners to education in the outdoors, despite the Learning Outside the Classroom Manifesto. This is largely the result of increasing financial pressures within schools and local authorities, meaning that the costs of these experiences can no longer be met. This is exacerbated by the concerns of teachers and Heads about the health and safety responsibilities which fall to them, and their lack of confidence in their own field skills. There is also greater bureaucratic burden on teachers associated with this form of learning. Fieldwork is less likely than before to be allowed during school time, because of the regulation introduced in September 2009 that teachers should only rarely be expected to provide classroom cover in colleagues' absence (the so-called 'rarely cover' rule), and that this should not usually be done when the absence can be foreseen. A further burden on staff time is that a group which can be taught by a single teacher in a classroom environment is likely to require more than one member of staff in the field. In addition, many teachers and Heads are concerned about the impact on delivery of the rest of the curriculum of taking children out of school – particularly following the introduction of Controlled Assessment which makes student absence from lessons problematic. This is a major factor in the development of stress and mental illnesses within the student body, and significantly reduces the rigour and enjoyment of learning. The impact of the modular exam system makes it still more difficult to find times to schedule trips outside school. These issues are all capable of resolution, but reflect the failure of the existing system properly to integrate field-based study in the school programme, despite its fundamental importance in a discipline such as Earth science.

What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

6. As mentioned above, health and safety are significant concerns for many teachers. It is important that health and safety considerations are taken seriously and addressed effectively, but teachers can be supported in doing this through appropriate Continuing

Professional Development. Some initial teacher training courses incorporate an element of training in outdoor education, but these skills need to be taught more widely and maintained on a regular basis. There may also be fear on the part of some teachers of legal action should something go wrong, and a lack of confidence that others in the educational hierarchy will be supportive. (This is also the case in Higher Education institutions, where it acts as a serious disincentive to staff.)

Do examination boards adequately recognise practical experiments and trips?

7. Recognition and support for practical work in science varies across the GCSE science awarding bodies, and this would be strengthened by an increased profile for practical work at a national level, and improved assessment. This is particularly true of investigational practical work.

8. Whilst fieldwork is a required element of the English National Curriculum in geography, this is not the case in science, and it is therefore not a requirement of GCSE science examinations with the exception of GCSE Geology – despite the inclusion of Earth science content in the science curriculum. It is a requirement of one of the two A-level Geology specifications, and a strong recommendation in the other.

9. More specifically, there is no requirement for field work at AS and A2 level in the OCR specification. Students can take a 'Centre Based Assessment' instead – in other words, an additional exam. Assessment of fieldwork has become very formulaic, and is presented in the context of a simplistic task-led depiction of 'how science works', of the kind which has led to disquiet about standards in schools science more generally. Synoptic tasks (in which fieldwork can make a particularly strong contribution) have been diluted and spread through the course. So although fieldwork can still be a part of the course, its place is not secure. This is due to the attempt to standardise specifications across the sciences in recent years, to the detriment both of geology and of holistic skills development. There may be scope for introducing further fieldwork opportunities through the Extended Project, but this initiative is in its early stages. Given all this, there is no doubt that if fieldwork were more strongly recommended in science specifications, and more thoroughly assessed, its prominence in schools would be significantly increased.

If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

10. Discussions with those in industry reveal clearly their need for students who have acquired a high level of practical and field skills. If children do not have the opportunity to develop these skills at school, their development later in life is all the more difficult. In particular, outdoor education not only fosters particular science skills, but also builds confidence in working in different environments outside the classroom.

11. Research evidence also indicates that well taught practical work and fieldwork has major impact on developing the thinking and investigational skills of students, in ways

that are valuable in all walks of life. Without these elements, science education is impoverished and less effective.

What changes should be made?

12. The Science and Technology Committee should offer their strong support for a national initiative to develop practical work in schools, with regard both for the number and quality of activities and how these can be used most effectively in educating the next generation of scientists, in developing children's interest in science, and in promoting the development of investigational skills and thinking across the population.

13. The committee should also promote a national initiative to develop investigational fieldwork across the sciences, for similar purposes to those outlined above. Not only is there good research evidence for the impact of fieldwork on students – both those who will eventually become scientists and those who will not – but there is a wealth of anecdotal evidence for the positive impact of fieldwork, on scientific skills as well as a wide range of transferrable skills, including social skills.

14. These initiatives should focus both on teachers in training and on those who are practicing.

Is the experience of schools in England in line with schools in the devolved administrations and other countries?

15. In Scotland, development of the Curriculum for Excellence is currently underway. This encourages a diversity of learning environments, including learning outdoors. The Scottish Government has a scheme to assist with the cost of transport so that schools can take children to science centres to engage in practical activities in environments outside the classroom. Across all the science disciplines, the Scottish Government, through the Scottish Qualifications Authority, is recognising that the development of practical skills should be the focus for producing the next generation of scientists that will contribute to a developing Scottish economy. This is not currently the case in England.

Concluding remarks

16. The Geological Society recognises the important role it can play in supporting school teachers – both specialist geology teachers, and those who bring aspects of Earth science into the curriculum in other subjects. We are developing our programme of activities aimed at school teachers and their students, including our Schools Affiliate scheme. In particular, we have recently started to run a Geoscience Education Academy – an intensive week of training aimed at those who are not specialist geology teachers. An important aspect of this training is to develop teachers' skills and confidence in fieldwork. We are keen to hear suggestions about other ways in which we can provide such support to teachers.

17. We would be pleased to discuss further any of the points raised in this submission, to provide more detailed information, or to suggest oral witnesses and other specialist contacts.

The Geological Society of London

11 May 2011

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Written evidence submitted by the Natural History Museum (Sch Sci 29)

Background and interests

1. The Natural History Museum (NHM) has a mission to maintain and develop its natural history collections to be used to promote the discovery, understanding, responsible use and enjoyment of the natural world.

2. The Museum is part of the UK's science base as a major science infrastructure which is used by our 350 scientists and over 15,000 others annually from across the UK and the globe working together to enhance knowledge on the diversity of the natural world.

3. Our value to society is vested in our research responses to challenges facing the natural world today, in engaging our visitors in the science of nature, in inspiring and training the next generation of scientists and in being a major cultural tourist destination. We welcome over 4.6 million visitors a year, including over 500,000 learning contacts.

4. The Museum welcomes the opportunity to make a submission to this Inquiry and have answered the questions where we have some expertise to enable us to answer them. We have an interest in this Inquiry as an out of classroom education provider, specifically in science education.

Question 1: How important are practical experiments and field trips in science education?

5. Visits to the Museum enable students to see the relevance of the science they learn at school by encountering real scientists practising real scientific research outside the classroom. The Museum's mission is to inspire our visitors about the natural world and science, combining collections and interpretation expertise to engender an understanding of humankind's place in and impacts on the natural world and the essence of scientific endeavour.

6. Museum visits assist students' conceptual development in science by providing extraordinary, memorable experiences, which target certain Curriculum concepts. The Natural History Museum, for example, is uniquely positioned to support conceptual understanding of evolution, the diversity of life and earth sciences. Teachers have told us that nothing communicates the timescale of evolution quite like a dinosaur skeleton, or geological processes quite like our rare rock collections. The Museum's collection of over 70 million specimens from the natural world provides a unique resource for revealing the sheer diversity of life on Earth. As well as using the collections themselves, interactive exhibits and props are used to support specific scientific concepts. Memorable Museum experiences can also take the form of practical workshops, debates or shows, facilitated by specially-trained

Museum educators using the Museum's unique resources that are unobtainable at school or elsewhere.

7. Practical experiments carried out by pupils at the Natural History Museum where real science takes place, using the same procedures as the Museum's scientists, is a particularly powerful, inspiring experience. Students position themselves as the scientist, making the role more attainable and appealing as a career. Students find it easier to understand Curriculum concepts addressing scientific process when carrying it out themselves in an authentic context. They also have the motivating experience of achieving success as doing 'real science': "*The students were enthusing about science all the way home, therefore it highly enhanced their attitudes towards their science learning. ….thanks for a brilliant session*" (Teacher Feedback, Wimbledon High School).

8. The Museum, through its citizen science programmes which aim to enthuse young people about their local environment through community participation projects like the Open Air Laboratories project: http://www.opalexplorenature.org/.

Question 2: Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

9. The Museum's Learning Department frequently consults with teachers to find out the best way to support their visits and classroom teaching. We constantly evaluate and analyse our school offer and its associated uptake.

10. Our total number of learning contacts for both Primary and Secondary level students have increased by 23% from 408,727 in 2009/10 to 531,366 in 2010/11 an increase of 122,639 contacts. However, broken down by key stage and also comparing with previous years, there are areas of decline within KS3 and 4. Looking only at Secondary students, in 2010/11 the Museum had 64,874 learning contacts. This was 7.5% decrease compared to 2009/10 (70,137 contacts) and a 6.5% decrease compared to 2008/09 (68,980 contacts). In terms of Secondary students taking part in our bookable activities and workshops, numbers for 10/11 compared to 09/10 were steady for KS3 (12,475 in 2010/11; 12,465 in 2009/10) and down by 4.5% for KS4 (1,629 in 2010/11; 1,707 in 2009/10). The decrease in bookings at the Museum is in line with a downward trend in Secondary school numbers across the out of classroom science learning sector as a whole. The Museum will devote energy to redressing this downturn in bookings in 2011/12 including continued consultation with teachers to find the best way to support their visits.

11. During a 2010 consultation exercise with teachers, 6 out of 11 teachers said that the Rarely Cover Policy would dissuade their senior management from organising school trips. This was attributed to the issues of taking staff away from lessons to maintain staff/pupil ratios required by museums and other out of classroom learning providers.

12. In Collins, S. & Lee, A. (2006) "*How can natural history museums support Secondary science teaching and learning? – A consultative study*" teachers reported barriers to a natural history museum visit. These included the amount of associated paperwork involved with taking a trip out of school and also transport difficulties.

Another factor was disrupting students' learning in other lessons, especially during GSCE years.

13. Transport difficulties were also mentioned as a possible barrier to a visit, although in London schools can access free public transport in addition to free entry and activities at the Museum. Also, teachers lacked confidence in student behaviour in unusual settings and felt that some providers lacked confidence dealing with Secondary groups.

Question 3: What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

14. The NHM's regular consultation exercises with teachers indicate that paperwork is a barrier to Museum visits, and this includes health and safety risk assessments, as well as parental consent administration. Teachers request that museums take measures to reduce the burden of paperwork, particularly by providing downloadable risk assessments. One teacher stated that it took 11 hours of paperwork to bring 80 students to The Manchester Museum (Collins, S. & Lee, A. 2006). We feel that while an awareness of a litigious society won't prevent the most committed teachers putting in the required effort to organise a school trip, the meticulous nature of risk assessment procedures provides a significant barrier for busy teachers to overcome.

Question 4: Do examination boards adequately recognise practical experiments and trips?

15. Within our schools offer, we have supported practical elements of the Science Curriculum and specific exam board requirements. We have a number of workshops developed to enhance students' learning and confidence with practical skills. In particular at KS4 we run the How Science Works at the Museum which supports the How Science Works element of the Curriculum, as well as Earth Lab which focuses on practical work with rocks, minerals and fossils. At KS5, we run a popular AS and A-level Biology focused day of activities, which was originally designed to support the work-based report element of the Salters Nuffield A-level Biology course, but is popular with A-level teachers and students in general.

16. The practical requirements of examination boards have benefited the Museum as it focuses our scientists and learning team on certain aspects of the Curriculum and the needs of students to develop practical skills and experience scientific research in practice.

Question 5: If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

17. The Museum employs 350 scientists and 50 education staff. The Museum provides opportunities for pupils to see real science in context, take part in authentic,

practical laboratory sessions, and to meet inspiring scientist role-models and discuss their research and its relevance.

18. It is crucial that students are able to develop technical skills as part of the Science Curriculum which they can then use in future careers. Also, having experience in practical science and talking with scientists who actually use these techniques will help them to make informed career choices.

19. It is crucial that we encourage and train future scientists and we can only do that by imparting knowledge, skills and experience as early as possible in their education. However, students who decide not to pursue a scientific career should leave education with a basic scientific literacy level.

20. The Natural History Museum, as a world-leading scientific research and cultural visitor attraction, is dedicated to preparing students for life as the next generation of scientists and scientifically literate individuals and aims to engage, enthuse and inspire young people in the subject.

21. The Natural History Museum works in partnership with regional museums (Great North Museum, The Manchester Museum, Stoke-on-Trent Museums, Oxford University Museum of Natural History) to provide innovative Science Curriculum-based activities for Key Stages 3-5 as part of the Real World Science programme. A key aim of the partnership is to inspire students to continue their scientific studies to A-level and university, and to take-up scientific careers. In the project's lifespan (2004 – 2011) over 78,600 students have taken part, including 21,155 in the year 2010/11.

22. Student feedback from our AS and A-level Biology days show that 29% of students found the day to have positively influenced their decision to continue Science at Further education and beyond. We have also had very positive feedback to this affect from other workshops. *"It allowed me to see a side of biology that I had not seen before. I really enjoyed it and would consider a career in Biological science or zoology."* (Richmond-upon-Thames College, 24.09.08).

Question 6: What changes should be made?

23. The Rarely Cover Policy protects teachers' vital lesson preparation and marking time. We believe that that teachers' ability to run school trips is being impacted as a result, due to senior school managers' reluctance to pay for externally sourced cover. We propose that, as a minimum, it be made compulsory that senior managers enable each student to experience one science trip to a museum at least once during Yrs 7-11. A consistent interpretation of the Rarely Cover Policy across schools is required, freeing up student access to rich cultural resources and to counter disadvantage.

24. Teachers have asked that out of classroom learning providers be encouraged/required to make risk assessment information, Curriculum links, and positive quotes from satisfied teachers, more readily available, helping teachers gain permission from senior managers to leave school grounds, and to help with administration.

15. That teacher training programmes require experience of organising a school trip, including risk assessment, building a wider culture of teacher confidence for taking groups out of school.

Joe Baker
Special Adviser, Department of Learning
Natural History Museum

11 May 2011

Written evidence submitted by EngineeringUK (Sch Sci 30)

About EngineeringUK

1. EngineeringUK is delighted to submit evidence to this important inquiry. We are an independent, not-for-profit organisation whose purpose is to promote the vital contribution that engineers, and engineering and technology, make to our society.

2. Our goal is to improve the perception of engineers, engineering and technology and improve the supply of engineers. Through our national programmes we engage with young people, and with those who influence them, to increase awareness of the wide variety of engineering careers on offer and the benefits and rewards they can bring. We see the role of extracurricular enrichment and enhancement activities/ field trips as paramount.

3. We lead the development and delivery of The Big Bang: UK Young Scientists & Engineers Fair[1], of which more later. This Fair, referred to as The Big Bang, is now in its third year and is funded by over 20 science and engineering firms, many in the FTSE 100, along with a wide range of not for profit bodies within the sector. In 2011 we saw over 25,000 young people, parents and teachers visit The Big Bang at London's ExCeL to participate in practical experiments and see first-hand innovation from the UK's leading science and engineering companies. We know from the level of participation in and excitement about The Big Bang that schools and young people are very interested in science and engineering when they have the opportunity to see it brought to life in this way.

Context – the economics of engineering

4. We have deliberately only answered the questions where we have relevant expertise and evidence and have interpreted the scope of science to include science, technology engineering and mathematics (STEM).

5. The engineering sector is already critically important to the UK economy, in March 2009 there were 482,880 engineering enterprises employing over 4.5 million workers and generating a combined turnover of £848.6 billion which equates to 19.6% of total GDP. In 2008 the manufacturing sector alone generated 55% of all exports. Government consistently looks to engineering to help rebalance the UK economy as well as serving to meet the grand global challenges of climate change, ageing population, clean water and security.

6. We know from our research that we cannot be complacent about ensuring the future supply of skilled technicians and engineers. Future demand as indicated by Working Futures III indicates that between 2007 and 2017 the manufacturing sector needs to recruit 587,000 new workers. This will be a challenge when you consider that from 2009-2020 the number of 18-year-olds will decline from 819,098 to 685,823.

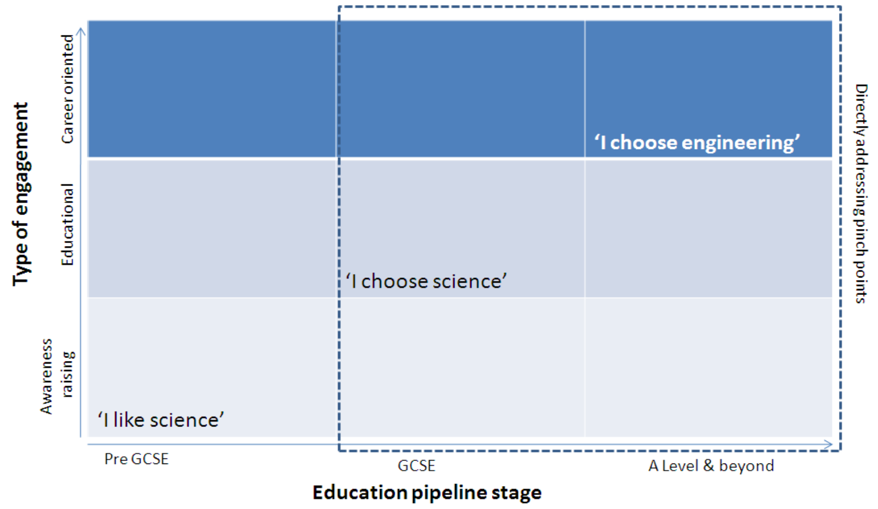
Context – the learner journey

7. EngineeringUK's purpose is focused on engineering and technology but we recognise that science and mathematics are the core subjects in school which underpin the future selection of engineering, whether that is in the context of further or higher education, or direct employment from school. We have worked with Boston Consulting Group for our

[1] http://www.thebigbangfair.co.uk/home.cfm

Tomorrow's Engineers programme in the West Midlands put this into context, building on the experience with business interventions in schools.

Engaging with Young People



8. We see learners go on a journey through liking science, choosing science and then choosing engineering, recognising that motivation, subject choice and then career choice form a natural progression. Awareness raising or inspiration is followed by solid educational initiatives that relate to the curriculum and ultimately the selection of a further or higher education route. All three types of engagement are needed to have an impact, with continuous evaluation as the basis for determining the right mix.

1. How important are practical experiments and field trips in science education?

9. When students eventually come to work within the STEM sectors, employers require them not only to have academic knowledge of their subject but also some degree of work-ready, hands-on practical skills and, if possible, related work experience. In this regard practical experiments and field trips or enhancement and enrichment activities (E&E), should be a critical core component for all young people.

10. In its 2011 report, Building for Growth: business priorities for education and skills, the CBI identified the top priorities for schools and colleges. Top priority was improving employability skills (70%), with improving literacy and numeracy coming second at 65%.

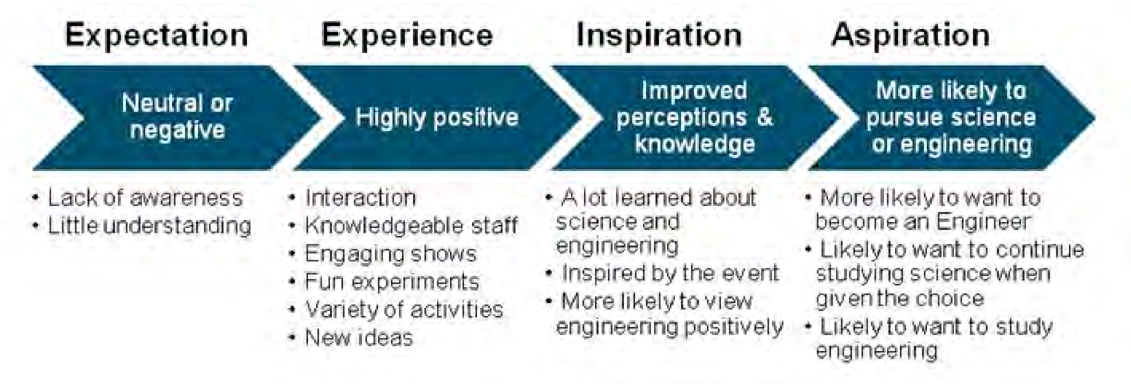
11. Our own research has shown that young peoples' positive experiences of field trips and enhancement and enrichment activities can influence them towards pursuing STEM subjects and, beyond that, considering careers in engineering.

12. Evaluation of the children attending The Big Bang, details of which can be found above, shows that their claimed understanding of science and engineering increased as a result of attending the event. When 5-11 year olds were asked at the event how much they had learned about science and engineering by coming to The Big Bang, 71% said they had

learned ‘a lot’ and 24% said they had learned ‘a little’. Visitors aged 12-16 were asked whether they agreed or disagreed with a series of statements about The Big Bang. 95% agreed that they had ‘learned something new about science at The Big Bang’; 85% that they had ‘learned something new about engineering at The Big Bang’. Three quarters of boys aged 12-16 and 81% of girls of the same age said that the visit to The Big Bang had changed their view of engineering either ‘slightly more’ or ‘much more’ positively.

13. The Big Bang had a positive impact on how likely children are to want to become an engineer. Three fifths of boys (61%) aged 12-16 interviewed at The Big Bang said that their visit had made them either ‘a little more’ or ‘much more’ likely to want to become an engineer. The proportion amongst girls of the same age was similar, at 58%. For some student visitors (those in the older age bracket) finding out more about career paths and asking about work experience and apprenticeships was their main motivation for coming to the event. One student went as far as printing off several copies of her CV, which she then handed out to staff manning stands associated with careers she was interested in.

14. The diagram below, illustrates the typical ‘journey’ of a student visitor who, prior to visiting The Big Bang, had relatively low engagement with science or engineering but at the end of the day left inspired by the event and more likely to consider science and engineering favourably.



5. If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

15. Within the STEM disciplines, we believe that that the decline in quality or numbers of activities will detrimentally affect the numbers of young people who wish to pursue STEM careers, in turn undermining the economic sustainability of the UK. We know that young people can be positively influenced through the use of carefully designed, planned and delivered E&E activities and our research has also identified strong views about the quality and availability of careers advice and guidance available to participants.

16. Young people's perceptions of STEM subjects and careers in STEM need to be improved. These subjects are currently seen to be the opposite of enjoyable and meaningful. Additionally, our research shows that[2] young people in the UK experience a prominent and consistent dip in their motivation and performance in the middle years of compulsory education (ages 11-14). This dip becomes more pronounced just after the stage of transfer from lower to upper secondary school (age 12/13) with the most evident dips in more traditional academic subjects including science and maths, while studies have shown that students demonstrate a preference for subjects with a practical orientation where learning is organised in an active, project-like way, such as art, technology subjects, music and textiles.

17. Enquiry-based learning via hands-on opportunities to experience science and engineering, as an approach to overcoming issues of perception at critical points in a student's school life shows some clear benefits: students are more engaged with the subject, perceive it as more relevant to their own needs, and are enthusiastic and ready to learn. Following their own research interests and allowing students to develop a more flexible approach to their studies, with the freedom and responsibility for what and how they learn, helps make subjects more relevant to them, leading to the development of original thought and ideas. Longer term, the skills gained working with and communicating to a group, are key to students' future employability in an increasingly 'knowledge-based' society.

18. We also are aware that young people's enjoyment is as significant as attainment as far as their likelihood to pursue a subject further. Pupils in the UK have been reported as having comparatively high levels of academic attainment and proficiency levels in science; yet, at the same time reported as having the lowest levels of enjoyment in science, with girls' enjoyment levels ranking significantly lower than boys.[3] Complementary research also shows that a major reason why children and young people give up science and maths is a lack of enjoyment and interest. The research shows that in the UK in recent years children's attitudes have become less positive and in some aspects we are losing ground against other countries. [4]

19. Focusing careers information at this time in a young person's life would be a useful way to proceed if we truly want to have an impact on the shortfall of engineers in the system. We strongly encourage the Government to develop a careers service that provides high quality careers education, information advice and guidance to young people across the UK prior to, at the time of, and beyond GCSE choices that promote the diversity of engineering careers available. The need for STEM teachers better to be informed on career paths, is highlighted from a finding in our own Engineering and Engineers Brand Monitor survey 2010. When STEM education professionals were asked what level of qualification you needed to become an engineer 47% said First Degree and 40% thought someone would need A Levels to become a Technician. In addition when they were asked what words they associated with engineering the most frequently mentioned words were design, mechanical and maths.

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[2] INCA: Dips in performance and motivation: A purely English perception? www.inca.org.uk/pdf/Final_Dip_Report.pdf

[3] OECD 2007: PISA 2006 Science competencies for tomorrows' world Volume 1, Volume 2, Data and Analysis: Paris

[4] Educating the next generation of scientists: House of Commons Committee of Public Accounts

6. What changes should be made?

20. At a national strategic level Government education policy must recognise that STEM subjects need adequate and inspiring combinations of practical and enrichment and enhancement activities/ field trips (within and extra-curricular). In its 2008 Report[5] Ofsted highlighted that learning outside the classroom contributed significantly to raising standards and improving pupils' personal, social and emotional development. Ofsted should be charged to evaluate how that this type of provision is being taken up in schools.

21. Government must also do all it can to ensure that young people, in the critical decision-making years (12 -14 years old) at secondary school, are shown through enrichment and enhancement activities, backed up by the provision of robust and comprehensive careers information, advice and guidance, all the exciting possibilities inherent in a career in science and engineering.

22. STEM employers, the net beneficiaries of skilled technicians and graduate engineers, can play a part in assisting schools and colleges to deliver better awareness of STEM career pathways and opportunities. The Big Bang[6] is supported by a large number of science and engineering organisations (over 150). This partnership approach positively engages young people at all levels and helps bring the realities of a career in science, technology and engineering home. We think that more must still be done to change perceptions about science and engineering as a career and can prove that engagement activities such as The Big Bang can positively change young people's perceptions towards the study of STEM subjects and pursuit of STEM careers.

23. Whilst we are recommending actions that still need to be implemented, EngineeringUK through effective co-ordinated partnerships with business, education, third sector and government is, at a national level, setting the pace on this issue. Over the past two years we have refocused our efforts to provide young people with exciting activities, useful careers information and improved perceptions of science and engineering through two key programmes:

The Big Bang: UK Young Scientists and Engineers Fair incorporates an annual national event, a series of regional and local fairs, and features the finals of the National Science & Engineering Competition. The biggest event of its kind in the UK, The Big Bang celebrates and raises the profile of young people's achievement in science and engineering, encouraging more young people to see where STEM might take them, with support from their parents and teachers. www.thebigbangfair.co.uk/home.cfm

Tomorrow's Engineers, provides targeted, high quality, and consistently evaluated enhancement and enrichment activities, featuring project-based learning opportunities and relevant hands-on experience. This is all underpinned by robust STEM careers information provision. www.tomorrowsengineers.org.uk/

5 Learning outside the Classroom, October 2008

6 http://www.thebigbangfair.co.uk/2011_sponsors.cfm

We would be happy to supply further information to the inquiry in both written and verbal form as required.

Paul Jackson
Chief Executive
EngineeringUK

11 May 2011

Declaration of interests

EngineeringUK is in receipt of grant funding from the Department for Business, Innovation & Skills and the Department for Education towards The Big Bang UK Young Scientists & Engineers Fair.

Key partners in The Big Bang UK Young Scientists & Engineers Fair

Led by

EngineeringUK

In partnership with

British Science Association

Institute of Physics

The Science Council

The Royal Academy of Engineering

Young Engineers

Written evidence submitted by The Wellcome Trust (Sch Sci 31)

The Wellcome Trust is pleased to respond to the Select Committee for Science and Technology's inquiry into practical work in schools. As a scientific organisation, we strongly believe that practical work is an essential element of every young person's science education. It helps them to develop the essential skills of scientific observation and inquiry and it stimulates their interest and enjoyment of the subject.

This letter sets out our experience as a major funder of science and science education and offers some references for the Select Committee to consider as it conducts its inquiry. In terms of defining 'practical work', we consider that experiences such as laboratory experiments, project work, fieldwork, and wider opportunities beyond the classroom (STEM clubs, trips to science centres or museums etc), all constitute important elements of practical science learning.

There is no doubt, and considerable evidence to show, that well planned and implemented practical work enhances young people's learning and understanding of scientific concepts. Furthermore, it increases their engagement in and enthusiasm for science subjects, and helps them to develop skills that are valued by higher education institutions and employers. We believe that schools should give all students the opportunity to design and carry out their own experiments, to experience scientific investigation first-hand, as well as witness high quality teacher-led practical demonstrations and visit STEM-related locations.

Beyond our overall support and encouragement for good and well planned practical work, we wish to make three substantive points.

Our first point is the need to recruit, train and retain high quality teachers and technicians. It is critical that STEM teaching at all levels incorporates a wide range of practical work through demonstration and enables young people to experience practical work themselves[1]. Without the appropriate specialist teachers and high quality technicians - who should all have access to regular subject specific continuing professional development (CPD) to keep up with the latest developments in science - crucial practical skills will not be passed on to learners.

In this regard, technicians must be recognised as essential contributors to the practical teaching of STEM subjects. They provide crucial support and guidance - particularly for newly qualified teachers and those teaching outside their specialism, who might otherwise lack confidence or experience in teaching practical lessons. The challenges around the future supply of school technicians is of particular concern and must be addressed[2].

The second point is our concern about the level and quality of practical work across UK primary schools. The 2007-10 Ofsted report calls for improvements around engaging primary school students in science and better CPD for primary teachers. Primary education is a young person's first experience of scientific experimentation and is crucial to setting the foundations of scientific

[1] Analysing Practical Science Activities to Assess and Improve their Effectiveness, Millar (2010) http://www.gettingpractical.org.uk/documents/APSsampleJan2010.pdf

[2] National Strategic Skills Audit for England, Skills for Jobs, Today and Tomorrow, UKCES (2010) http://www.ukces.org.uk/reports/skills-for-jobs-today-and-tomorrow-the-national-strategic-skills-audit-for-england-2010-volume-1-key-findings

literacy. It is therefore important to develop young people's attitudes towards science and mathematics at primary and early secondary ages through positive and inspiring experiences[3].

In this regard, we suggest that the Select Committee consider the role of the Primary Science Quality Mark that has been established to improve the quality of primary science. We believe that this is an important and high quality initiative, but it requires national recognition if it is to reach all schools. It is also clear to us that there is a real demand from primary school teachers for well designed kits of practical material. We were extremely pleased with the positive response that we had in 2009 when, in partnership with the Royal Botanic Gardens, Kew, we sent a 'Darwin Box' to every primary school in the UK. Following a comprehensive external evaluation, we established that the boxes were used by an estimated 13,000 (60%) primary schools[4], with highly positive feedback.

Our third and final point is to say there is a real opportunity to improve upon young people's engagement and attainment in science, by placing an increased emphasis on scientific project work. A Wellcome Trust funded educational project provides a good example of this. Students at Simon Langton School were given the opportunity to carry out experiments to help understand the causes of multiple sclerosis (MS), with help from their teachers and scientists at the University of Kent[5]. Since the start of this project in 2008 the number of students at that school taking A-Level Biology increased from 44 to 82 in 2010[6].

The Extended Project also gives students the opportunity to work on substantial scientific projects. It provides a valuable and authentic scientific learning opportunity for students and is highly regarded by both HEIs and employers. All schools and colleges should be given encouragement and guidance on using the Extended Project to support science education programmes and to provide opportunities for exploring ways of working used by professional scientists.

We would be happy to supply evidence or additional information to this letter if required.

Sir Mark Walport
Director
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11 May 2011

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Written evidence submitted by the Institute of Education, University of London and the University of York (Sch Sci 32)

How important are practical experiments and field trips in science education?

Practical work

1. The aim of science is to find explanations that are supported by evidence for the events and phenomena of the natural world. As such, practical work is an essential part of effective science education. Teaching science involves, by its very nature, showing students things or putting them into situations where they can manipulate objects and materials and see certain things for themselves. In this respect a fundamental purpose of practical work in school science is to help students make links between the natural world of objects, materials and events and the abstract world of thought and ideas. Furthermore, by enabling students to undertake practical work for themselves, they are also able to experience firsthand the distinctive way in which much of our current, as well as past, scientific knowledge about the natural world has been derived.

Field trips

2. Whether science is taught in a specialised laboratory (as in many secondary schools) or in a typical classroom with some specialist equipment (as in many primary schools), the fundamental idea is that students are presented with a simplified version of reality in which it is easier for them to be introduced to key scientific ideas. Unless complemented by the richer, messier world outside of the classroom students may fail to connect their classroom learning with the world beyond the classroom. Braund and Reiss (2006) have argued that we can envisage three categories of this outside-of-the-classroom world:

- the actual world (e.g. as accessed by field trips and other visits to see science in use);
- the presented world (e.g. in science museums, botanic gardens and zoos);
- the virtual world (e.g. through simulations).

3. Learning in the actual, the presented and the virtual world can valuably complement learning about science that takes place within school. Even during their school years students spend most of their waking hours outside of school.

Are practical experiments in science lessons and science field trips in decline? If they are, what are the reasons for the decline?

Practical work

4. Practical work is a traditional and well-established part of science education and we are not aware of any research evidence that would suggest that the number of practical experiments is declining. Indeed, Bennett (2003) has claimed that there is little reason to believe that the amount of practical work has diminished from the

level reported by Thompson in 1975, who found that one third of all 17-18 age range science teaching time was devoted to some form of practical work, with this rising to one half of science teaching time for students aged 11-13 (Beatty & Woolnough, 1982).

Field trips

5. In the UK, there is consistent and worrying evidence for a substantial decline in science fieldwork over the last 50 years (Lock, 2010). There are a number of reasons for this decline. The science National Curriculum (introduced in 1989) has reduced considerably the autonomy of science teachers and there is a common perception that fieldwork takes students away from what they are meant to be learning in the classroom. Although science fieldwork is actually extremely safe, a small number of high profile accidents on field trips (though usually on adventure courses) have put many schools, teachers and parents off the idea while teaching unions have cautioned about organising field visits in the light of health and safety concerns; perhaps unsurprisingly, teacher confidence in taking students outside is variable (Ofsted/HMI, 2004). There have also been concerns about the consistency of fieldwork training for secondary science pre-service teachers (Kendall, Murfield, Dillon & Wilkin, 2006), while parents/carers often have difficulties meeting the costs of fieldwork, particularly when residential. As a result, students at independent schools are more likely to benefit from field trips than students in the state sector (Association for Science Education Outdoor Science Working Group, 2011).

What part do health and safety concerns play in preventing school pupils from performing practical experiments in science lessons and going on field trips? What rules and regulations apply to science experiments and field trips and how are they being interpreted?

Practical work

6. Risk assessment in the school laboratory is a necessary and important part of ensuring safe practical work. There is no evidence that we are aware of to suggest that teachers' awareness of health and safety issues have led to any noticeable reduction in either the amount or type of practical work used in schools. However, there is some anecdotal evidence, from visits to schools by one (IA) of us, that a small number of teachers have stopped doing certain experiments – for example electro-statically charging a healthy student using a Van de Graaff generator – because they mistakenly believed that to do so is no longer permitted on 'Health and Safety' grounds. Similarly there is evidence from the Royal Society of Chemistry (2011) that "teachers and technicians have misconceptions about the type of experiments that are banned in UK schools" and that these misconceptions, rather than actual health and safety issues, are causing some teachers not to do carry out practical experiments that would otherwise be acceptable. In many schools risk assessment for practical tasks is now embedded in schemes of work to such an extent that for many teachers health and safety is simply a matter of following the guidance provided in the light of their knowledge of a particular group of students.

Field trips

7. The present rules and regulations that apply to field trips are appropriate, except in a minority of cases where Local Authorities are unduly restrictive. What is more important, and concerning, are the frequent and widespread urban myths about the volume of form filling and the time required to deal with the attendant bureaucracy. The reality is that a risk assessment needs to be carried out and the depth with which this needs to be undertaken should be proportional to the possible harms. Most field centre providers give assistance to schools in completing such assessments.

Do examination boards adequately recognise practical experiments and trips?

Practical work

8. Awarding bodies (examination boards) include some assessment related to practical work in both A level and GCSE sciences. In fact at A level the sciences are an exception to the norm of just four units of assessment. When the QCA consulted about the revision of subject criteria for A level, both the science community and the science education community lobbied for six units of assessment to allow for the assessment of practical work to continue, partly in the belief that if it was not assessed there would be less incentive to carry out practical work and there would be a pressure for more science to be taught in classrooms, rather than laboratories. The current criteria state that 'Each of the internally assessed units at AS and A2 must include the assessment of practical skills' (QCA 2006). The activities assessed range from prescribed experiments to full practical investigations. At GCSE, from 2012, 25% the marks are awarded for 'controlled assessment', which assesses students' ability to plan and carry out tests of scientific hypotheses. Attempts to include the direct assessment of practical skills such as constructing a circuit, setting up a microscope or carrying out a titration have been abandoned as being too difficult to validate.

9. There is substantial anecdotal evidence that some teachers consider the model of assessment of practical work offered by the awarding bodies as a key criterion when choosing which specification to adopt – not because they think it is the best on educational grounds but because it will be the easiest for their students to score good marks on, and the easiest for them to mark and administer.

Field trips

10. It is difficult to overstate the importance of the specifications (syllabuses) set by the awarding bodies at GCSE and A level in driving teacher practice. One of us (MR) has spent twenty years with very little success trying to get fieldwork to be a required part of A level biology courses. From the awarding bodies' point of view, this is too risky a strategy. Such compulsion would almost certainly lead to a loss in the number of candidates taking their courses as too many teachers would be likely to move their students to courses that did not require fieldwork.

11. The GCSE criteria for Additional Science and for Biology include the requirement that "specifications must require learners to demonstrate knowledge and

understanding of fieldwork techniques to explore the relationships between communities of organisms and their environments" (Ofqual 2009).

12. This means that fieldwork techniques should be incorporated into schemes of work so that students are able to answer questions in examinations.

If the quality or number of practical experiments and field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

Practical work

13. What should be noted here is that whilst the amount of practical work has remained relatively constant the way in which it has been assessed at GCSE level since 1987 has led to an emphasis on investigative exercises of a very narrowly conceived kind – chosen in order to make it as easy as possible for students to score high marks. These are widely seen (Donnelly et al., 1996) not to have much educational value, and to present a flawed image of the science enquiry process. They have, however, squeezed out illustrative practical work, designed to enhance understanding of scientific concepts and phenomena, and to develop skills in using scientific equipment and procedures. Indeed, our experience is that many teachers of biology, chemistry and physics in Higher Education say that students come with almost no hands-on experience of handling common bits of scientific equipment.

14. Even though there is a lot of practical work being undertaken it is important to recollect that the reported *preference* for doing practical work amongst many students *within* science lessons (Abrahams, 2011) does not necessarily imply that practical work is an effective means of motivating large numbers of students to pursue the study of one or more science subjects in the post-compulsory phase of their education. For whilst these students undeniably *do* like practical work, their reasons for doing so appear to be primarily that they see it as preferable to non-practical teaching approaches that they associate, in particular, with more writing.

Field trips

15. Many reviews of science education in the UK and other developed countries show that although school students begin their secondary science education with enthusiasm, by the time they leave school most of them are glad to leave school science, all too often describing it as boring or irrelevant (Osborne & Collins, 2000). In contradistinction, field trips in science are often extremely motivating for students. A recent, large-scale evaluation of residential science field trips for over 30,000 11-14 year olds from 850 London schools from 2004-2008 (Amos & Reiss, in press) found that that students' collaborative skills and other social relationships were strengthened and persisted back to school. Gains were strongest in social and affective domains alongside high levels of conceptual engagement, while there were also cognitive gains. There were particular benefits for students from socially deprived backgrounds who gained from exposure to authentic learning environments.

What changes should be made?

Practical work

16. Rather than simply suggesting that teachers should do even more practical work than they are currently doing there is a need to focus on how to improve the effectiveness of the practical work that science teachers already use, even if the result of this means that they end up doing less, but more effective, practical work in their lessons. This approach is primarily what the Getting Practical: Improving Practical Work in Science (IPWiS, 2011) project has been about in that it was essentially designed to encourage teachers to reflect more fully and deeply on the learning objectives of the practical activities they use and, in particular, the kinds of thinking that such practical work requires of students if it is to be effective in developing conceptual understanding. A key way to achieve this is to help science teachers not only to see, but also to use, practical work as both a 'hands on' *and* 'minds on' activity, rather than the essentially 'hands on' activity that it is currently widely seen to be (Abrahams & Millar, 2008). The impact of such a change would be that students would not only 'do practical work' but would actually understand *why* they were doing it and what they were learning from doing it – something that is frequently less than clear to many of them – as well as being better able to *understand* and *explain* what they see and do using the scientific terminology and ideas that explain the phenomena and/or data that they produce.

17. Whilst the IPWiS evaluation has shown that one short CPD programme cannot transform practice, it did show how systematic reflection on practice, focusing on aspects of the design of practical activities that research suggests are critical to effectiveness, could and did stimulate significant changes in practice. There is therefore a need for coaching and on-going support, not only in the form of sustained long-term continuing professional development – ideally in the national and regional science learning centres – but also extensively within Initial Teacher Training programmes, if substantial and durable change to the effectiveness of practical work in school science is to be achieved.

18. There is a also a need to recognise that science is primarily about understanding the natural world – and the natural world, outside of the school science laboratory, does not contain a large number of exciting bangs, flashes and pops. If we can show students that the real excitement of science comes from *understanding* those phenomena, then we might in fact succeed in motivating more students towards an intellectually fascinating subject.

Field trips

19. The subject criteria for A level biology (including AS) should require at least one field trip to be undertaken. Serious consideration should be given to making some form of learning out of the classroom compulsory for A level (including AS) chemistry and physics too. While these subjects do not need field trips in the way that biology does, they benefit greatly from such learning experiences as chemistry trails and industry visits (Braund & Reiss, 2004).

20. Science students, whether at primary or secondary level, training to receive QTS (Qualified Teacher Status) should be trained more rigorously than is often the case at present to take students on science field trips.

21. The science National Curriculum, which is currently being revised, should clarify the relationship between learning science inside and outside of the classroom and provide age-appropriate requirements for learning science outside of the classroom.

Is the experience of schools in England in line with schools in the devolved administrations and other countries?

Practical work
22. Our experience is that the use and perceived value of practical work varies not only from country to country but also from school to school, and often from teacher to teacher. The UK is, however, one of a very small number of countries in which school science lessons are taught predominantly in laboratories rather than classrooms, and one of even fewer in which schools typically have science technicians to support the practical work undertaken by teachers. Whilst we are unaware of any systematic study that compares the amount or type of practical work used in different countries, it is widely recognised that more practical work is carried out in school science teaching in the UK than in most other countries.

Field trips
23. We are unaware of any rigorous study comparing field trips in different countries. Our experience is that the situation in most developed countries is that same as in England, namely that there is general willingness to allow science field trips to take place, and a realisation that they can have considerable benefits, but organising them at secondary school is typically left to individual teachers / science departments. The result is that field trips remain the preserve of the minority of students fortunate enough to have an enthusiastic science teacher who believes in the value of such trips. Over time, the number of such teachers is probably declining.

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Robin Millar is Salters' Professor of Science Education at the University of York. He has directed and/or participated in several major research projects, including the EU Labwork in Science Education project. He made an invited presentation on the role of practical work in school science to a National Academies Committee in Washington, DC in 2004. He recently helped to design the instruments and approaches used to design the CPD programme for the Getting Practical: Improving Practical Work in Science project.

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Michael Reiss is Professor of Science Education and Associate Director (Research, Consultancy and Knowledge transfer) at the Institute of Education, University of London. He has received funding for research on science practical work and field trips from the DfES, DCSF and the Field Studies Council.

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Written evidence submitted by SCORE (Sch Sci 33)

About SCORE

SCORE member organisations aim to improve science education in UK schools and colleges by supporting the development and implementation of effective education policy. SCORE is chaired by Professor Graham Hutchings FRS and comprises the Association for Science Education, Institute of Physics, Royal Society, Royal Society of Chemistry and Society of Biology.

SCORE welcomes the opportunity to provide evidence for the Science and Technology Committee's inquiry into practical experiments in school science lessons and science field trips.

In summary the SCORE response covers the following:

- The importance of practical work[1] in the teaching of the sciences to the 5-19 cohort. Good quality practical work develops a range of skills, science knowledge and conceptual understanding and it promotes the engagement and interest of students - all of which is likely to impact positively on learner progression in the sciences, both into higher education and careers. This is vital in meeting the growing demand from employers for STEM[2] skills, and in maintaining the UK economic competitiveness.
- The enablers of practical work in the sciences for the 5-19 cohort. Appropriate teacher and technician support, resourcing and assessment are essential if science departments and primary teachers are to use good quality practical work in the teaching of the sciences.
- Improving the quantity and quality of practical work in the sciences. It is suggested this is through: evidence based research to inform the design, assessment and resourcing of practical work; accountability to ensure all young people have access to good quality practical work; and the promotion of good practice and resources.

1. Importance of practical work in the teaching of the sciences to the 5-19 cohort

1. SCORE members regard high quality practical work as an integral element of all teaching and learning in the sciences. This was also noted in the recent report from Ofsted[3]. SCORE considers practical work to encompass learning activities in which students observe, investigate, and develop an understanding of the world around them through:

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[1] In this document the term practical work refers to practical laboratory and classroom activities and field work.

[2] STEM (Science, Technology, Engineering and Mathematics)

[3] Ofsted *Successful Science* Jan 2011 http://www.ofsted.gov.uk/Ofsted-home/Publications-and-research/Browse-all-by/Documents-by-type/Thematic-reports/Successful-science

- having direct, often hands-on, experience of phenomena or manipulating real objects and materials, and

- where primary data/observations are not possible or appropriate, use secondary sources of data to examine experimental observations (for example: aerial photographs to examine lunar and earth geographic features: spectra to examine the nature of stars and atmosphere: sonar images to examine living systems) [4].

2. Good quality practical work should have three overarching purposes[5]:

   - It enables and enhances the learning of scientific concepts and explanations and ensures students have seen what they ought to have seen in order to understand a scientific idea; sometimes this is by giving them an experience or feeling of a phenomenon, particularly an abstract one such as inertia. Much of the practical work that takes place in schools will be intended to bridge the conceptual gap from the world that students see around them to the more abstract representations used by scientists.

   - It engenders an understanding of scientific process, enabling students to experience and understand the difference between the knowledge claims made by the sciences and those made by the humanities. Through practical activities students experience what it is like to 'think like a scientist' and have a 'cultured' approach towards science education, understanding 'why they know what they know' and 'how they know what they know' and not merely accepting knowledge as fact[6].

   - It develops laboratory skills. Students should be given opportunities to develop their manipulative skills through the use of apparatus and by following protocols.

3. As well as developing these essential skills, good quality and appropriate practical work is widely acknowledged to promote the engagement and interests of students towards the sciences, which is also likely to impact positively on learner progression in the sciences, both into higher education and careers.

4. In addition, practical work contributes specifically to the teaching and learning of biology, chemistry, physics, and primary science:

   - The Society of Biology regards high quality practical work in biology as activities that: illustrate the beauty and complexity of the living world;

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[4] Lunetta, V N, Hofstein, A and Clough, M P *Teaching and learning in the school science laboratory. An analysis of research, theory, and practice* 2007 pg 394

[5] The Gatsby submission to the Government's Call for Evidence for the review of the National Curriculum April 2011

[6] The SCORE submission to the Government's Call for Evidence for the review of the National Curriculum April 2011 http://www.score-education.org/media/7650/scorencevidence.pdf

promote an understanding of how to extract information from complex living systems; provide an experience of testing hypotheses and analysing and evaluating variable data; support the teaching of mathematical, statistical and modelling skills; highlight and promote discussion of ethical issues; give students the foundation of skills to continue into academic or vocational training and ultimately enable them to tackle global challenges[7].

- The Royal Society of Chemistry regards high quality practical work in chemistry as activities that: allow students to experience the wonder of chemistry; are integral to teaching rather than extension activities; deliver learning outcomes; provide opportunities to illustrate scientific ideas; allow students to apply their knowledge and understanding to investigate and test scientific theories; reinforce the theoretical concepts and content in a way that generates enthusiasm and excitement in the students; allow students to interpret the reliability of data and the validity of scientific claims; provide students with the opportunity to develop the skills necessary to meaningfully interact with chemical issues and challenges in their future lives either as scientists or as informed citizens.

- The Institute of Physics regards high quality practical work in physics as activities that: illustrate the concepts taught theoretically in lessons e.g. interference, diffraction, thermal expansion, latent heat from a cooling curve, ray optics; stimulate skills in independent investigation; develop laboratory skills in physics and handling laboratory apparatus; reinforce the idea that physics is an experimental discipline and that many of the major theoretical and experimental advances have been stimulated by unexpected experimental results; and develop an appreciation of the need to think about accuracy in measurement and of experimental errors.

- The Association for Science Education regards practical work activities to lie at the heart of primary science. Children need opportunities to develop practical and enquiry skills in order to engage with the world in a scientific way and to make sense of what they are learning about living things, the environment, materials and physical processes. Hands-on experience promotes curiosity and engagement and provides opportunities for the discussion and questioning which develop understanding. Practical work can take place inside or outside the classroom, and can happen at any point in a unit of work or lesson. It may be a five minute demonstration, a short activity to practice using an unfamiliar piece of equipment or an extended enquiry. What it must be is a varied and integral part of the

[7] Society of Biology *Practical biology position statement* December 2010 http://www.societyofbiology.org/policy/policy-statements/practical-biology

learning process via appropriate learning objectives which promote progression in both skills and content knowledge, through activities for thinking as well as doing.

5. SCORE acknowledges that in the UK more practical work takes place in science lessons than in most other countries (indicated by international comparisons such as TIMSS). However, there remains concern among the science community that schools in general are not doing enough (or doing the right kind of) practical work and that its quality is uneven[8].

6. High quality practical work develops the skills which employers (STEM and non-STEM related) and Higher Education Institutions demand. It stimulates creativity, curiosity and critical thinking; illustrates concepts, knowledge and principles; underpins knowledge formation; promotes student engagement with the scientific method; encourages active learning and problem solving; allows collaborative working; and provides opportunities to collect and analyse data and apply mathematical skills.

7. In a recent CBI report, 43% of employers in the UK were reported to be having difficulty recruiting staff with skills in STEM, with manufacturers and science-related businesses having the most difficulty finding highly-skilled people to fill their posts. Even more companies (52%) expect to have difficulty finding STEM-skilled people in the next 3 years[9]. The education system must support young people in developing STEM skills not only for the individual learner to progress but for the UK to maintain its commercial competitiveness in the world.

8. While the importance of practical work is well documented, all education policy must be based on strong evidence. SCORE would therefore like to see further commitment to research designed to ascertain the impact of practical work on students' attitude, attainment and progression in the sciences. A greater understanding of the role that practical work plays in the learning process at all stages of science education would enhance our ability to design, assess and resource good practical work in the future.

2. Enablers of practical work in the teaching of the sciences for the 5-19 cohort

2.1 Appropriate resourcing of facilities, consumables and equipment

9. If the Government is to maintain its commitment to STEM and to increase the number of young people progressing in science education, it must be prepared to appropriately resource science education. The sciences are a statutory requirement in the National Curriculum. They are practical subjects and by this very nature often more expensive than other school subjects.

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[8] SCORE *Practical work in science: A report and proposal for a strategic framework*, 2008 http://www.score-education.org/media/3668/report.pdf

[9] CBI Building for growth: b*usiness priorities for education and skills, Education and skills survey 2011* May 2011 http://www.cbi.org.uk/ndbs/press.nsf/0363c1f07c6ca12a8025671c00381cc7/f14c02961d1d92ac8025788800442fdb/$FILE/CBI_%20EDI%20Education%20&%20Skills%20Survey%202011.pdf

10. There is well-documented evidence of the shortfalls in funding for equipment and upkeep of laboratories. These funding inadequacies should be addressed within a wider strategy aimed at improving laboratory facilities.[10] All secondary schools should have access to well-maintained, well-equipped, well-designed, dedicated laboratories and adequate access to functioning ecosystems to support field work. Primary schools should also have appropriate access to practical work, including access to functioning ecosystems.

11. To the best of our knowledge, despite recent government initiatives in England such as Building Schools for the Future and Project Faraday which aimed to improve laboratory facilities, there has been no monitoring on the improvements achieved. There are also concerns that these programmes were not sufficiently informed by science teachers' and technicians' needs[11].

12. At secondary level, senior school management must ensure that science departments have adequate funds to maintain and refurbish laboratory facilities. At primary and secondary level, senior school management must ensure their schools can afford the purchase and upkeep of consumables and equipment that enable practical work activities. It is important schools also budget for scientific field work activities. These may include transport costs to sites and payment to field studies centres. It should be noted there are also a number of ways that schools can undertake field work activities without incurring these costs.

2.2 Technician support

13. School science technicians are essential to the delivery of laboratory and field work in secondary schools and therefore in providing a high quality science education. In their report[12] CLEAPSS (Consortium of Local Education Authorities for the Provision of Science Services) state that 'experienced and skilled technicians can give direct support to practical activities ... by ensuring that a wide range of apparatus and materials is available, appropriately maintained and stored effectively. Technicians not only contribute to the health and safety, economy and efficiency of the department, but they also enable science teachers to offer varied and stimulating science lessons'.

14. In 2002 the Royal Society and the Association for Science Education estimated that up to 4,000 additional science technicians were required to provide adequate technical support to

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[10] RSC *Laboratories, Resources and Budgets: Provision for science in secondary schools* April 2004 http://www.rsc.org/ScienceAndTechnology/Policy/EducationPolicy/Laboratories2004.asp and RSC *Improving school laboratories? A Report for the Royal Society of Chemistry on the number and quality of new and re-furbished laboratories in schools* October 2006 - http://www.rsc.org/images/Labsreport_tcm18-65943.pdf

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[12] CLEAPSS *Technicians and their jobs* Updated August 2009 http://www.cleapss.org.uk/attachments/article/0/G228.pdf?Free%20Publications/

all school science departments[13]. There is already a known shortfall in technician support and there is concern among SCORE members that the devolution of funding from central government to schools may result in an increased shortfall. Anecdotal evidence suggests that reductions in technician staff time as well as redundancies have already occurred in a number of science departments.

15. The Association for Science Education collects technician workforce data every 10 years[14]. The 2010 data, in comparison to the 2000 data set, suggests a number of trends which the Select Committee should consider:

- The school technician workforce represents an aging population with numbers between 50-60 years of age up by 50%.

- An increasing number of school technicians (up to 29%) are the only wage earner in the household.

- In 2000 the majority of technician posts required O-level or GCSE qualifications. In 2010 this number has fallen and posts are now more likely to be advertised for graduates. In addition the number of graduate technicians has changed from 22% to 37%, but there are now fewer graduates from City and Guilds.

- There is also a noticeable difference in the duties carried out by technicians, particularly in demonstrating practical activities to teachers (87% from 37%), to students (69% from 38%) and to other technicians (73% from 32%). In addition, 96% commented that one of their duties was to try out new practical activities (an increase of 11%) and 85% stated that they were responsible for setting up IT equipment, up from 70%.

16. It is crucial that senior school management recognise and support the need for a high quality science technician service. Senior school management should, for example, be aware of the minimum requirement for technician time which was developed by CLEAPSS and Association for Science Education[15]. This calculation is based on the service factor of 0.65 (or ideally 0.85) recommended by the Association for Science Education to ensure adequate technical support in the science curriculum.[16]

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[13] The Royal Society and The Association for Science education *Supporting success: science technicians in schools and colleges* January 2002 http://royalsociety.org/Supporting-success-science-technicians-in-schools-and-colleges/

[14] ASE *UK School Technicians Survey* 2010 – 486 respondents IN PRESS

[15] CLEAPSS *Technicians and their jobs* Updated August 2009 http://www.cleapss.org.uk/attachments/article/0/G228.pdf?Free%20Publications/

[16] The Royal Society and The Association for Science education *Supporting success: science technicians in schools and colleges* January 2002 http://royalsociety.org/Supporting-success-science-technicians-in-schools-and-colleges/

17. It is essential technicians are supported in their work and accorded the professional status they deserve. There should be substantial investment in technician continuing professional development (CPD)[17]. The CLEAPSS guide explores this in further detail.[18]

2.3 Health and safety

18. The 2008 SCORE report[19] and the 2011 report by the Outdoor Science Working Group of the Association for Science Education[20] found that although there are currently no serious threats to practical science from health and safety requirements, there is a negative impact resulting from perceptions of the restrictions imposed by regulations, particularly in the arrangements for field trips. Health and Safety legislation was never intended to inhibit the teaching of practical science but to ensure that it is carried out with minimum risk. It was designed to protect the health and safety of employees (e.g. teachers and laboratory technicians) and those affected by those work activities (students), not to prevent them from undertaking practical work in school laboratories.

19. The Health and Safety at Work Act (1974) as amended, applies to all workplaces, including schools. This means that the schools via their employers (the Local Authorities) have a duty to ensure the health and safety of teachers, technicians and students. In fulfilling this duty, schools and their governing bodies need to be satisfied that adequate arrangements are in place to ensure that laboratory activities are carried out safely. Practical science can be taught in schools without risk to the health and safety of students provided appropriate precautions are taken.

20. The Royal Society of Chemistry 2005 report ‘Surely that’s banned?’ illustrates in detail the level of misconceptions of assumed banned experiments and the implications this has on practical work[21]. The risks associated with the teaching of practical science need to be kept in perspective. Public understanding suggests that Health and Safety legislation is the main reason why chemistry experiments are prohibited, even though very few cases of injury to children have been recorded. In fact, legislation does not ‘ban’ any chemicals or procedures likely to be used in school chemistry. The fear of litigation has led to health and safety legislation being used as an excuse to avoid the teaching of practical chemistry skills.

21. Laboratory-based classes make a positive contribution to understanding the sciences and should be actively encouraged. Governing bodies should be reassured by

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[17] The Royal Society and The Association for Science education *Supporting success: science technicians in schools and colleges* January 2002 http://royalsociety.org/Supporting-success-science-technicians-in-schools-and-colleges/

[18] CLEAPSS *Technicians and their jobs* Updated August 2009 http://www.cleapss.org.uk/attachments/article/0/G228.pdf?Free%20Publications/

[19] SCORE *Practical work in science: A report and proposal for a strategic framework*, 2008 http://www.score-education.org/media/3668/report.pdf

[20] Outdoor Science: a report from the Association for Science Education Working Group, January 2011 http://www.ase.org.uk/news/ase-news/the-uks-leading-science-education/

[21] RSC *Surely that’s banned* October 2005 http://www.rsc.org/images/Surely_thats_banned_report_tcm18-41416.pdf

knowing that, even in today's risk-averse society, provided that proper risk assessments have been carried out and appropriate risk controls or precautions are in place, all reasonable steps have been taken to safeguard the safety of students. Evidence suggests that practical science in schools does not and has not, posed a significant risk to students.

22. Specifically for chemistry, the more specific Control of Substances Hazardous to Health (COSHH) Regulations apply. The COSHH Regulations (2003) require the assessment and control of risks associated with work activities involving the use of hazardous substances, which includes most chemicals. All that is required to teach practical chemistry safely is to look at the way in which chemicals are used and to consider how to control the exposure to these chemicals by students (and teachers) so that any risks to health and safety are acceptably low. The COSHH Regulations do, however, prohibit the use of a very limited number of specified substances that are not, in any case, used in schools. The COSHH Regulations do not imply that the use of other chemicals are "banned" or that experiments are "prohibited". Nevertheless, anecdotal evidence suggests that some Local Authorities (LAs) and school governing bodies are citing legislation as a reason to discontinue practical chemistry teaching. Anxious parents have contributed to this situation by expecting a risk-free environment for their children.

23. There is, however, a need to be vigilant that amendments to existing regulations and new proposed legislation do not unintentionally restrict the teaching of practical science.

24. Guidance should also be provided to teachers and their employers (LAs) about what is and is not permitted with regard to practical teaching and in this regard information on the hazards likely to be found in school laboratories is given in the data sheets published by CLEAPSS, the Association for Science Education, SSERC (Scottish School Equipment Resource Centre), Heath and Safety Executive and the Royal Society of Chemistry. Specifically for primary schools the Association for Science Education has developed the publication *Be Safe!*[22] to provide guidance on health and safety matters for those teaching primary science.

25. With respect to scientific fieldwork, it should be noted by the Committee that field work in geography is commonplace in schools and colleges, despite facing the same apparent barriers encountered by science.[23]

2.4 Teacher support

26. In the SCORE practical work report[24], the main reasons cited for teachers' confidence in undertaking practical work were experience (including experience gained e.g. as a scientist,

[22] Association for Science Education *Be Safe! Fourth Edition* 2011
[23] Tilling, S. *Fieldwork in UK secondary schools: influences and provision. Journal of Biological Education*, 38(2), pg 54-58 2004

prior to becoming a teacher), knowing the subject and having enthusiasm for it. Teachers surveyed in the SCORE report also responded that they did not necessarily feel confident in carrying out practical work outside their specialist discipline, and in a recent ASE survey[25], 33% of teachers felt inexperienced in practical work.

27. As teachers should feel confident in the learning objectives of each practical activity and be confident in undertaking the activity with the students, it is important that practical pedagogy is embedded at Initial Teacher Education level. It is also vital that all science department staff (teachers and technicians) and primary teachers and subject leaders have access to high-quality CPD to enable them to respond to changing student needs but also to changes in the curriculum, changes in available equipment/technology and changes in legislation regarding health and safety.

28. SCORE supports the Getting Practical programme, hosted by the Association for Science Education, which provides professional development to support teachers, technicians and high level teaching assistants at primary, secondary and post 16 levels in the delivery of effective practical work in the sciences. The Department for Education has unfortunately decided not to continue funding this programme beyond July 2011. SCORE regards it as essential that the work and messages of the Getting Practical programme should continue[26].

29. Although practical work across the sciences has many similarities, there are also differences. For instance in each of the sciences there are specialist pieces of apparatus, specific techniques as well as different learning outcomes in terms of knowledge and ways of thinking. Therefore, whilst there is overlap in the skills needed to carry out and manage effective practical work in each of the sciences, there are also subject-specific skills which are more likely to be associated with subject specialists.

30. The severe shortage of chemistry and physics specialist teachers has resulted in much of the responsibility for students' secondary science education falling on the shoulders of teachers with biology or general science qualifications. For the immediate future this will continue to be the case (it is estimated by the Institute of Physics that even if an extra 1000 physics teachers a year are recruited, it will take 15 years to address the current imbalance of specialist teachers in the sciences). This is likely to have an impact on the quantity and quality of the specialist laboratory and field work that takes place in the individual sciences and therefore on the student's attitude towards these subjects. There is, therefore, a long term need to encourage and support teachers in using practical work outside of their specialism.

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[24] SCORE *Practical work in science: A report and proposal for a strategic framework*, 2008 http://www.score-education.org/media/3668/report.pdf

[25] ASE survey on practical work and fieldwork - 388 respondents April 2011

[26] Getting Practical *A report on the achievements of the programme 2009-2011* May 2011 http://www.ase.org.uk/documents/getting-practical-report/

31. Subject-specific CPD should be an entitlement for science teachers as part of their overall CPD entitlement, including instructions on contemporary science and developments in research techniques. For specialist subject teachers this should provide them with opportunities to remain engaged with their subject and to grow and develop teaching expertise in their specialism. For non-specialist teachers, subject specific CPD should help to address any relevant gaps or misconceptions in their subject knowledge and pedagogical content knowledge. At secondary school level the Stimulating Physics Network and Chemistry for Non-Specialists programme aim to tackle this specifically. In a report from the Royal Society it was recommended that there is a similar need for a 'science for non-specialists' course at the primary and lower secondary level. This would help develop teacher confidence in using practical activities in the teaching of the Key Stage 2/3 science curriculum[27].

32. SCORE would like to see a commitment to ensuring that individual school and college science departments have a balanced and full complement of science subject specialist teachers to teach courses in physics, chemistry and biology. This would enable science departments to support the delivery of practical work by less experienced teachers, training teachers and those teaching outside their specialism, through mentoring schemes, sharing good practice and observation. At primary school level it is equally important non-science specialist teachers are supported to use practical work in their science teaching.

2.5 Assessment

33. There are concerns that the current assessment demands are damaging and restricting for practical work. In the SCORE report[28] and a recent survey from the Association for Science Education[29], exams and assessment were listed by secondary teachers as the second most common constraint to the delivery and quality of practical activities in science lessons (exceeded only by constraints in the curriculum). Assessment should not drive the science curriculum (of which practical work are integral) yet with league tables and accountability it continues to do so.

34. SCORE recommends the following points are considered on how practical work should be assessed:

- There are arguments that the assessment of practical work ensures its place in the science curriculum and helps protect the provision of facilities.

- While SCORE supports the removal of national tests at the end of Year 9, it has led to the secondary science curriculum being increasingly driven by the assessment requirements of GCSE. SCORE also

[27] Royal Society *Science and mathematics education, 5-14 – a state of the nations report* July 2010 http://royalsociety.org/State-of-the-Nation-Science-and-Mathematics-Education-5-14/

[28] SCORE *Practical work in science: A report and proposal for a strategic framework*, 2008 http://www.score-education.org/media/3668/report.pdf

[29] ASE survey on practical work and fieldwork - 388 respondents. April 2011

supported the removal of the Key Stage 2 National Tests for science, as they distorted the primary science curriculum. However, an unintended impact of this change led, in some cases, to less time being spent on science. There is a perception in some schools that science is no longer important (or core).

- Since its introduction in 1988, the National Curriculum has required students to undertake their own investigative work at Key Stage 4. While SCORE supports the intentions of such investigative work in developing practical skills, assessment targets encourage schools to concentrate on investigations which maximise student performance rather than develop a range of laboratory skills. In many cases this has resulted in practical activity that is narrow in scope and variety and quite often repetitive.

- Controlled assessments have contributed to the limited scope and breadth of practical work. This is because practical tasks set by awarding organisations in controlled assessments must meet the following requirements; be deliverable within a 30-60 minute slot; 100% reliable; deliver results for every student; be prepared by a technician quickly; and use equipment available in every school in the country.

35. There is a need to explore and research effective ways to assess practical work, and to support awarding organisations in developing appropriate examination questions.

36. Teachers also require support in the assessment of practical work. Teachers need to be clear what it is that they would like students to know, understand and do, and whether their assessment approaches are fit for purpose. Teachers' understanding of the purposes, validity and reliability of the various approaches to assessment in all its guises still appeared to be a significant factor in what and how they teach.[30]

2.6 Time and variety

37. In order to be effective, practical work at primary and secondary level must be well planned, with an understanding of clear learning outcomes. This requires substantial time to be set aside for teachers and technicians to develop activities; under current pressures this time allocation simply does not exist.

38. In the SCORE report[31], and a recent survey from the Association for Science Education[32] time constraints were cited by teachers as a major barrier. A recent survey

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[30] A SCORE commissioned study by Justin Dillon and Robert Fairbrother, King's College London and Robin Miller, University of York IN PRESS

[31] SCORE *Practical work in science: A report and proposal for a strategic framework*, 2008 http://www.score-education.org/media/3668/report.pdf

[32] ASE survey on practical work and fieldwork - 388 respondents. April 2011

by Professor Justin Dillon[33] also found that teachers reported that time for planning individually and collectively was inadequate. This was particularly true of teachers who were not qualified in the subject that they found themselves teaching. This reinforces the need for an increased workforce of specialist science teachers. Schools have also commented on the amount of time allocated to science and the length of lessons.

39. The science curriculum in schools should allow sufficient time and space for teachers to undertake a wide range of practical activities with their students. Practical work in schools should include, but not be restricted to, investigations and enquiry activities. Students should experience authentic investigations during school science where students formulate meaningful hypotheses (i.e. in contexts where they have not been taught the expected answer already) and where there will be more than one cycle of activity. There is already some expertise around in this regard, for example the British Science Association's CREST scheme, but it is classed as extra-curricular, and is not available to students unless schools opt-in.

40. Other practical activities should include assembling apparatus, pre-defined procedures, observation and measurement tasks, analysis, experience of phenomena, field work and teacher demonstrations.

41. It is important however to distinguish between quantity and quality. The quality of practical work experiences should be judged by the progress students make in their learning, and be measured against agreed success criteria. Practical work should not be judged by the quantity of time spent on it. For example, complete investigations will probably be rare activities, as elements of the investigative process and of the practical techniques can be studied in shorter time periods.

3. Improving the quantity and quality of practical work in the sciences through evidence based research, accountability and promotion of good practice

3.1 Evidence based research

42. SCORE is embarking on a major research project to investigate the resourcing of practical work that currently takes place in schools and colleges in England. This work will update existing datasets on the appropriate levels of resourcing required to enable practical activities to take place. A baseline for equipment and consumables was first developed by the Royal Society in 1997[34]. This was subsequently enhanced and updated by the RSC in 2004[35] and 2006[36] to include laboratory facilities. In addition, in 2008 CLEAPSS and ASE[37] developed a baseline for technician support.

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[33] A SCORE commissioned study by Justin Dillon and Robert Fairbrother, King's College London and Robin Miller, University of York IN PRESS

[34] Royal Society *Science teaching resources: 11 – 16 year olds* 1997

[35] RSC *Laboratories, Resources and Budgets: Provision for science in secondary schools* April 2004 http://www.rsc.org/ScienceAndTechnology/Policy/EducationPolicy/Laboratories2004.asp

43. Given the new levels of autonomy given to schools, this work will demonstrate to senior school management the resource requirements of a science department. On a national scale, the work will demonstrate the level of funding required to best support science education. It will also enable a wider scale investigation into how many schools and colleges in the UK currently reach an acceptable standard.

3.2 Accountability

44. Good quality practical work is integral to science and all young people should have access to it through their science education. There should be a mechanism in place to ensure all schools and colleges are able to (and do) provide this.

45. Ofsted provides such a mechanism and SCORE welcomes the reference to practical work in the Ofsted subject specific guidance documents in science. However, these subject specific inspections operate on a very small scale. SCORE strongly recommends that Ofsted increases the number of subject specific inspections to provide statistically useful data on the impact of policies, structures and initiatives in school departments, particularly with respect to practical laboratory and field work.

46. Field work in geography is currently a statutory requirement within the National Curriculum and therefore is to be experienced by all students. Field work is just as vital to the sciences as it is for geography, particularly in the teaching and learning of biology, yet it and practical laboratory work are not given the same statutory protection. This is counterproductive to efforts to promote practical work in the sciences.

47. The recent SCORE submission to the Government's Call for Evidence on the review of the National Curriculum urged the content statements in the National Curriculum to be written in such a way as to recognise that the sciences are to a large extent practical subjects, and for the statutory guidelines to include explicit reference to procedural skills in the laboratory and in the field[38].

48. In 2004 it was reported by the RSC[39] that a quarter of all school science facilities were graded as unsafe or unsatisfactory, and a further 41% were basic/uninspiring. This is not acceptable and there is a strong case that schools should be held to account on their practical laboratory and field work facilities. The major SCORE research project referred to in Paragraphs 42 and 43 will provide essential information to ensure this is possible.

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[36] RSC *Improving school laboratories? A Report for the Royal Society of Chemistry on the number and quality of new and re-furbished laboratories in schools* October 2006 - http://www.rsc.org/images/Labsreport_tcm18-65943.pdf

[37] CLEAPSS *Technicians and their jobs* Updated August 2009

[38] The SCORE submission to the Government's Call for Evidence for the review of the National Curriculum April 2011 http://www.score-education.org/media/7650/scorencevidence.pdf

[39] RSC *Laboratories, Resources and Budgets: Provision for science in secondary schools* April 2004 http://www.rsc.org/ScienceAndTechnology/Policy/EducationPolicy/Laboratories2004.asp

49. As part of its regulation of awarding organisations Ofqual should be held responsible for ensuring that specifications and all accompanying textbooks support high quality practical work.

3.3 Resources and promotion of good practice

50. Since the publication of the SCORE strategic framework[40] for the enhancement of practical work in science in schools and colleges there has been a strong, coordinated approach from the science community to raise the profile of practical work and to maximise the awareness of the support that is available. This should continue to be the basis for any future work.

51. The framework produced by SCORE in 2008 was distributed to all primary and secondary schools[41]. The framework gave a definition of practical work in science, described the purposes of practical work and proposed ways to implement effective practical work in schools. Accompanying the framework were dedicated resources that linked the indicators of high quality practical work to selected biology, chemistry and physics activities for primary and secondary schools.[42]

52. These messages and showcasing of good practice are also supported by the Getting Practical website[43] and the Practical websites[44] which were developed by Nuffield Foundation and CLEAPSS in collaboration with the Society of Biology, Royal Society of Chemistry and Institute of Physics. These websites include tried and tested physics, chemistry and biology experiments, in sufficient detail that they will work in any school laboratory. In addition, the sites provide notes about teaching and learning, demonstrate an integrated approach to the development of mathematical skills and advice on health and safety issues. The sites support teachers and technicians who wish to develop their practical skills in the sciences, and are regularly updated.

53. Members of SCORE play a leading role in supporting the use of high quality practical work through a variety of schemes. SCORE members also actively promote collaboration between schools, colleges, universities and other stakeholders to facilitate sharing of practice aimed at enquiry based practical learning.

54. There are many resources available for teachers and technicians to support practical laboratory and field work. It has been reported to SCORE that a significant number of calls to the CLEAPSS Helpline refer to problems in published protocols for practical activities. While it would not be helpful to require specific practical activities in the National Curriculum Programme of Study, teachers need to be able to recognise good-quality material. Materials sent to CLEAPSS by publishers for health & safety checks often include activities that simply

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[40] SCORE *Practical work in science: A report and proposal for a strategic framework*, 2008 http://www.score-education.org/media/3668/report.pdf

[41] http://www.score-education.org/media/3662/framework.pdf

[42] http://www.score-education.org/media/3677/secondary.pdf and http://www.score-education.org/media/3674/primary.pdf

[43] http://www.gettingpractical.org.uk/

[44] www.practicalbiology.com , www.practicalphysics.com , www.practicalchemistry.com

do not work. Resources on practical work should be checked for suitability and practicality before publication. The Practical websites mentioned in paragraph 52 provide one example of where this principle is already in place**.**

SCORE

11 May 2011

TSN
TEACHER SCIENTIST NETWORK

10.05.11

The Clerk
Science and Technology Committee
House of Commons
7 Millbank
London, SW1P 3JA

Dear Sir/Madam,

Please find enclosed a Memorandum from the Teacher Scientist Network to the Science and Technology Committee following its call for evidence to support its inquiry into practical experiments in school science lessons and science field trips.

The Teacher Scientist Network (TSN) is a registered science education charity. This submission has been prepared by its coordinator, Dr. Philip H. Smith, MBE. The registered office and correspondence address for the TSN is the John Innes Centre, Norwich Research Park, Colney Lane, Norwich, NR4 7UH.

I would be very happy to discuss this submission and be questioned upon it during oral evidence given to the committee.

Yours faithfully

Dr. Phil Smith, MBE
TSN Coordinator

Written evidence submitted by the Teacher Scientist Network (TSN) (Sch Sci 34)

Summary

Herein we highlight the unique and highly important role practical science provides to young people of all ages. There are many real barriers in the classroom to providing effective science practical lessons and these barriers – the types of investigations, a lack of curriculum time, resources, and the support of teaching staff and money – are often compounded together to have a detrimental effect upon young peoples understanding and ability in the sciences. This lengthy supply chain from school to University to STEM employers is adversely affected along its length potentially damaging the recovery of UK plc and its places a world leader in Science and Technology. Suggestions and exemplars follow.

Introduction:

This submission, on behalf of the Teacher Scientist Network, has been prepared by Dr. Philip H. Smith, MBE, coordinator. It represents the views of the teacher-dominated TSN Steering Group that guide our activities. These are geared towards enhancing local school science in Norfolk and North Suffolk with the active involvement of the local science community.

Our teacher membership numbers approximately 300 teachers who teach science at all phases of education: primary to sixth-form. TSN was formed in 1994 and is a registered charity receiving funding from a variety of sources through grant-income. TSN is independent from but generously hosted by John Innes Centre in Norwich providing a strategic base for our activities within the Norwich Research Park.

The importance of practical science

1. It is widely accepted that future developments in Science and Technology will underpin the growth and development of the UK economy and UK plc. Such developments require an ongoing supply chain of talented pupils both interested and able to push forward the boundaries of our present understanding in science. How can we help foster this supply chain? Whilst knowledge and facts about science can be gathered from peer reviewed journals, text books and the internet, the opportunity to engage young people in 'learning by doing' in carrying out their own investigations and experiments is a unique facet of science the importance of which needs to recognised by school authorities and regulatory organisations everywhere. Such opportunities engage learners of all ages, exciting them and contributing to their wish to study the sciences further at University and beyond.

2. However, we accept that only a small percentage of pupils will become future scientists. The remainder of the pupil population will become those, who unless they have a thorough understanding of science, potentially mistrust science and scientists and are more easily led by misleading media headlines. We would argue therefore that our aspiration for a more 'scientifically literate society' will support the development of a strong science base in the UK.

3. These aspirations require mechanisms to develop the innate curiosity and knowledge in our young people about the world around them and the way in which the world and its components are organised and work. Practical science lessons and science field trips are powerful, and almost unique, ways to achieve this.

4. Every week the feedback TSN receives from our teacher members supports the idea that practical experiments in science lessons and science field trips are in decline. The reasons for this are cited as a packed curriculum, heavily dominated by knowledge gathering (with implications on timetable time for practicals) and, in some cases, a lack of resources.

Issues of time and resources

5. In 2009, Darwin year, when working with teachers to develop resources to aid teaching and learning in Evolution, high school teachers suggested to us that they were required to cover the topic in about 3 hours of teaching time which clearly leaves very little time for practical investigations once the theory component has been covered.

6. Time will also have an impact on the use of field trips. Many curriculum areas will be enhanced by visits to science institutes or science departments of local Higher Education Institutes (HEIs), many of which are keen to host such visits). The House of Lords Science Committee, Science in Society, February 2000 were actively encouraging research scientists to facilitate such visits, "*It is the responsibility of research scientists to communicate to the rest of us the excitement of making new discoveries and the importance & implications of their work."* Research centres like the John Innes Centre and the Institute of Food Research (both funded by the BBSRC) ably support staff and students in enhancing the student experience of such visits to the site. Such visits enable the applied nature of the science they are learning in school to be actively demonstrated.

7. The combination of coach costs and the impact of a half or full-day 'away from school' makes many teachers question making such visits even though their value (when well organised) has been recognised for sometime. The ASE Chief Executive was quoted in June 2002 saying "s*cience education in schools can only benefit when teachers and pupils have direct contact with professional scientists and the world of work.***"**

8. This problem however is not a new one – the Teacher Scientist Network (TSN) was formed in 1994, at the launch of the then 'new' national Curriculum. TSN facilitates the formation of 1:1 long-term, sustainable links between teachers and scientists, who work in partnership, allowing the scientist to bring 'real-science' direct to the classroom. This eliminates the problems associated with time away from the classroom but still presents a challenge to be able to carry out engaging and relevant practical's in the limited time allocated to practical science in the classroom or laboratory. A range of other activities – Master Classes, Kit Club endeavour to bringing teachers closer to 'real life science.' *Most importantly TSN activity is delivered in a 'bottom-up' way providing what teachers ask for, not what some large organisation, removed from the classroom, thinks they need*.

Supporting teachers: training and continued professional development

9. When the National Curriculum was introduced the Norwich Research Park was approached to consider how best the science community could be used to support local science teaching. It was felt that the most effective mechanism was to make long-term partnerships between teachers and scientists. At this time, primary science teachers did not feel confident enough to teach science effectively (and this situation continues today[1]) and high school teachers were concerned that they were not up-to-date. TSN continues to make these links, and currently has approximately 60 partnerships operating across Norfolk and North Suffolk. These scientists are supported by senior managers from across the Norwich Research Park allowing staff to take time out to work with their teacher partners in the classroom. The work is vital and supports the development of teacher confidence to successfully implement practical sessions in the classroom that are well-designed and addressing real-life research challenges (and therefore more engaging). Whilst the value of practical science cannot be under-estimated, it is important the practical is done well.

10. In calling for more to be done to raise the profile of practical science, TSN urges the Committee to recognise that good practical's in school science lesson are facilitated by good teachers themselves supported by good science technicians. Good teachers are those who are confident teachers, up-to-date in their subject knowledge and practically adept themselves. These teachers will be those most able to inspire future scientists.

11. The development of such teachers begins with the training of new teachers (best supported by the post-graduate certificate of education (PGCE) delivered widely at HEI's around the UK). Students on the PGCE science course offered by the University of East Anglia, benefit from a 1-day workshop about using modern biotechnology procedures in the classroom (teachers learning 'on the job' do not have such opportunities). Techniques such as restriction digestions, polymerase chain reaction, bacterial transformations are ubiquitous in life-science laboratories around the world and in the classroom offer pupils the chance to experience relevant modern laboratory techniques. Providing trainee teachers with the skills to carry out these practicals in their own classroom increases the likelihood that such practical lessons will engage and inspire young people. The other component of this, the availability of sufficient resources to carry-out the practical, is addressed in paragraph 15 below.

12. Beyond their PGCE, teachers need to be able to keep up-to-date. To achieve this they need to receive sufficient, high-quality continued professional development (cpd) enabled by the full support of the Senior Leadership Team (SLT). The enabling aspect includes non-teaching time or time away from school and the funds to support attendance on courses. The continued support of the Department of Education for the Science Learning Centre Network is to be applauded but too often such centres are not able to recruit sufficient numbers of teachers on their courses because of the absence of senior management support for science cpd (in terms of funding and time and the rarely cover issue). As a result many of the courses offered by the SLC's are required to focus upon assessment diluting the subject knowledge component.

13. TSN actively promotes the GIFT workshop for teachers. A 2.5 day, pan –European workshop to enrich teachers subject knowledge with a different theme each year. As the UK representative for this event, TSN has found it increasingly difficult to fill its quota of 4-funded places for UK teachers particularly in the last 2 years. Strong anecdotal evidence from TSN teachers suggests that finding support from the SLT for 3 days away from school to develop their subject knowledge cannot be justified. The workshop is held in parallel with the European Geosciences Union (EGU) General Assembly and so the dates are fixed by this event. Teachers receive from the EGU a stipend to cover accommodation, meals and travel.

14. TSN's Master Class programme for high-school teachers continues to provide an almost unique opportunity for teachers to focus upon their subject knowledge, reinvigorating their interest in a subject and bringing themselves up-to-date in a particular topic. Topics for TSN Master Classes are suggested by teachers themselves and not designed to cover just curriculum material. The bigger picture enthuses and excites teachers, and the more able ones extract components of the day to enrich their teaching. The Master Class programme (www.tsn.org.uk/Master_Class.htm) includes lectures from leading academics from around the UK in the morning and relevant practical activities in the afternoon.

Lack of resources

15. So often teachers reported to TSN that they lacked the resources to carry out practical science (particularly in primary schools). With this in mind, TSN started to develop its Kit Club in 2000 to provide a library of free-to-loan resources for teachers to borrow. They both encourage hands-on investigative science and provide essential curriculum materials (eg. torso and skeleton) that schools don't have the budget or space to provide (http://www.tsn.org.uk/kitclub.htm). Again, the content of the Kit Club is built upon teacher

input – what teachers ask for to help them deliver more hands-on science in their classrooms. Importantly many of the resources facilitate hands-on, investigative science, recognising the true value of experiential learning in the classroom.

16. The rapid and sustained growth of TSN's Kit Club (both in terms of the number of schools who are registered users (presently 213), and the number of kits available to loan (100), is evidence of the limited availability of sufficient, high-quality, affordable resources in schools, particularly primary schools. Such deficiencies clearly would have a negative impact on practical science teaching in our schools were it not for the availability of TSN' free-to-loan resources in the Kit Club.

Health and Safety

17. Heath and Safety concerns have certainly had a negative impact on the amount of practical work carried out in UK schools. Although, the direct impact may be less than the perceived impact. In other words, many teachers believe certain practicals are banned when in fact they are not (a report by the RSC in 2005 supported this perception, http://www.rsc.org/ScienceAndTechnology/Policy/EducationPolicy/SurelyThatsBanned.asp). Another RSC publication first published in 1995 (Classic Chemistry Demonstrations: One Hundred Tried and Tested Experiments) was subsequently cited by Harrison[2] as timely to support chemistry teachers, http://www.rsc.org/images/Classicdemos_full_tcm18-198883.pdf).

18. Additionally, the lengths teachers must now go to to provide documented risk assessments has certainly hindered their willingness to organise practical lessons. Risk assessments are carried out before a practical and teachers try to think of every possibility, but children are sure to come up with some direction you hadn't anticipated! That of course is the beauty and thrill of open-ended investigations, allowing children to follow and develop their own curiosity, yet this can be constrained by health and safety.

Consequences

19. Whilst the timing of this inquiry is to be applauded, TSN feels the focus on 11-18 is an oversight. The central understanding of how to carry-out a scientifically valid investigation is laid down in primary schools ('a fair-test'). Additionally, with the preponderance of non-specialist teachers in the primary sector, many find the scientific enquiry aspect of the curriculum difficult to teach. Regretably, many primary practicals tend to be very prescriptive, and therefore predictable, suppressing both the teachers and pupils enthusiasm. The consequence of this is that some pupils will have decided that 'science is not for them' by aged 11 so potentially the raft of 14-19 initiatives will be lost on such pupils.

20. Teachers also report to us that the practical investigations at KS4 for GCSE are very ineffective at preparing students to feel confident with the scientific method.

21. The lack of practical experience has huge impacts at university level. Many students do not know how to do quite simple manipulations such as filtration or the correct use of a burette or a pipette. The lack of teaching basic laboratory and field skills in schools, undermines any attempt to teach these subjects at an advanced level and impacts on the skills base offered to employers seeking to employ technician grade employees aged 16+.

Future Developments

22. TSN believes that the curriculum needs to provide more opportunity for open-ended investigations at all ages – primary through to sixth-form. The relevance and importance of following the scientific methods needs to emphasised and learnt by doing. The science community should be encouraged and enabled to support science locally (after all it is in their

own interests). Pupils respond differently to 'their scientists' than 'their teachers' and this can have positive outcome on their learning.

23. In highlighting what appears to be a need for curriculum change, TSN is conscious that the one thing teachers would welcome is a sustained period of time without change! This would allow time for the many preceding changes to become embedded and some formal evaluation of success or failure to be gauged. During this time, certainly the creative and talented teachers (of whom there are many) may feel galvanised to research and develop their own new practicals. The withdrawl of KS3 SATs has certainly provided a small opportunity for them to do this. However, at the end of the day, senior managers will need a curriculum / performance driver in order to actively promote such an opportunity and this would need to be identified.

References.

1. Harlen, W. *Science as a key component of the primary curriculum: a rationale with policy implications*. Perspectives on Education 1 (Primary Science), 2008: 4-18. http://www.wellcome.ac.uk/perspectives

2. Harrison, T. Review of "*Classic Chemistry Demonstrations: 100 tried and tested experiments* by Ted Lister, in Science in School Issue 13, Autumn 2009. http://www.scienceinschool.org/print/1044

Declaration of Interests

The coordinator of the Teacher Scientist Network ia a member of the partners executive of the East of England Science Learning Centres, based at Bayfordbury, Herts. The SLC network is referred to above in Paragraph 12 (https://www.sciencelearningcentres.org.uk/centres/east-of-england).

The TSN Steering Group comprises teachers from across the region from primary and secondary education and representatives from each of the Institutes and HEI's supporting TSN's activity. Affiliations of the members of the TSN Steering group can be found at http://www.tsn.org.uk/contacts.htm

Teacher Scientist Network

11 May 2011

Written evidence submitted by The Royal Geographical Society (with IBG) (Sch Sci 36)

1. The Royal Geographical Society (with IBG) is the learned society and professional body for geography. Formed in 1830, for 'the advancement of geographical science' we are a world centre for geography supporting research, education, expeditions & fieldwork, and promoting public engagement and informed enjoyment of our world. We have 15,000 members and Fellows and a network of 1,000 School Members and Chartered Geographer (Teachers).

2. The Society has an established reputation in supporting schools to undertake fieldwork in the local area, further afield and overseas. Each year we provide continuous professional development training for more than 1,000 teachers and presentations to 25,000 pupils, fieldwork summer schools for pupils and fieldwork master-classes for teachers. Our Geography Outdoors centre trains teachers as Educational Visit Coordinators; provides the Off-Site Safety Management course; and was central to the development of the British Standard 8848 for the "provision of visits, fieldwork, expeditions and adventurous activities outside the UK". The Society led the Fieldwork section of the Department for Education funded Action Plan for Geography[1] (2006-11), creating extensive online fieldwork resources.

3. The Society welcomes this opportunity to comment on the inquiry into practical experiments in school science lessons and science field trips, focusing on our expertise and experience in geographical fieldwork. The Society wishes to makes the following points in this submission:

3.1 Geography is the *only* National Curriculum subject with a statutory requirement for fieldwork. This enables pupils to apply their learning to the real world and better understand the physical and human geography of their local area and places further afield. Ofsted has strongly supported geographical fieldwork[2] and identified *"how good and regular fieldwork motivated pupils and enhanced their learning in geography (and) encouraged a higher than average take up of examination courses.[3]"* The Society's response to the National Curriculum Review-Call for Evidence argues that fieldwork should remain a compulsory part of a statutory geography curriculum.[4]

3.2 Geographical fieldwork is an *existing* opportunity for 'scientific' enquiry; particularly through fieldwork focused on physical and environmental geography involving sampling, recording and presenting data and the use of digital Geographical Information Systems. We note that, at university level, geographical research has been recognised as 'part-STEM' by the Higher Education Funding Council for England. This is based on the fact that HE level scientific geographical research, including fieldwork, requires and attracts significant funding to ensure the necessary science-based infrastructure is in place.

3.3 However, there are 'overlaps' between the National Curriculum in geography and science; which include earth sciences, the water cycle & rivers, and weather and climate. These areas lend themselves well to fieldwork, although the Society understands that many science teachers view them as of less relevance. For example, a National Science Learning Centre consultation of 600 science teachers showed that they identified 'earth sciences' as one of the *least* popular subjects to be included in the science curriculum. To address this, the Society has recommended, in its National

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[1] See www.geographyteachingtoday.org.uk/fieldwork
[2] Geography: Learning to make a world of difference. Ofsted (Feb 2011)
[3] Geography: Learning to make a world of difference pg 4 Ofsted (Feb 2011)
[4] Society's response to the National Curriculum Review consultation (2011) http://www.rgs.org/NR/rdonlyres/0BD2C4C4-4DDB-4C48-831B-708F58F03C15/0/NCReviewresponseformRGSIBGresponsefinal1.pdf

Curriculum Review – Call for Evidence response, that earth sciences, the water cycle and rivers and weather and climate be identified solely within the geography, rather than the science, curriculum.

3.4 The removal of course work from examinations and introduction of controlled assessment has reduced some schools commitment to geographical, and possibly scientific, fieldwork. The requirement for fieldwork in GCSE & A Level geography examinations should continue and new opportunities should be provided for pupils' fieldwork to be better reflected in these examinations. The Society welcomes the ASE's call for *"greater flexibility provided to awarding bodies to significantly increase open-ended summative assessment and assessments that recognise skills developed through fieldwork[5]".* However, there has been no systematic research to understand whether the introduction of controlled assessment has impacted on school decision-makers support for fieldwork or on the range, type and duration of fieldwork offered. We suggest that such research be undertaken as a matter of urgency[6].

3.5 The Society believes there are opportunities for positive fieldwork collaborations between geography and science school departments, based on the distinct subject disciplinary contribution provided by these subjects. We note that the ASE highlighted the potential for integrated fieldwork planning especially in science, mathematics and geography[7].

3.6 The Society notes how the current challenging financial environment (in schools, LEAs and on parental contributions towards fieldwork) could place additional pressures on the abilities of schools to undertake fieldwork. For example, we understand 12 field centres are currently being closed, whilst a further 48 are 'at risk'[8]. These centres receive 300,000+ visitors pa. Such closures have the potential to place greater demands on the need for teachers to have skills and confidence to undertake 'self-led' fieldwork. The range of CPD support provided by the Society is well placed to help support teachers develop the abilities to lead their own fieldwork activities.

3.7 The Society believes that periodic monitoring of the type, location and duration of fieldwork provided in geography and science should be undertaken by the Department for Education and within relevant subject specific reports by Ofsted.

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Director
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11 May 2011

[5] Outdoor Science, Association for Science Education pg 5 (Jan 2011)
[6] The Society would be pleased to carry out such research if modest funds to do so were available.
[7] Outdoor Science, Association for Science Education pg 13 (Jan 2011)
[8] NAFSO survey of 89 field centres Feb 2010: 12 centres earmarked for closure (63,780 visitors pa) and a further 60 centres 'at risk' (259,400 visitors pa)

Written evidence submitted by The Campaign for Science and Engineering (CaSE) (Sch Sci 37)

1. The Campaign for Science & Engineering (CaSE) is a membership organisation aiming to improve the scientific and engineering health of the UK. CaSE works to ensure that science and engineering are high on the political and media agenda, and that the UK has world-leading research and education, skilled and responsible scientists and engineers, and successful innovative business. It is funded by around 750 individual members and 100 organisations including industries, universities, learned and professional organisations, and research charities.

2. Science and engineering are critical to the UK's social and economic future. Demographic trends in Europe and further afield mean that this country must strengthen its medium- and high-skills sectors in order to be competitive.

3. Despite this imperative, the UK still struggles to train enough young people with science and maths skills. The CBI reported in May 2011 that 43% of employers struggle to recruit enough staff with STEM (science, technology, engineering and maths) skills. A lack of practical experience and lab skills was the fifth most commonly cited reason for this difficulty[1].

4. Further, our PISA (programme for international student assessment) scores in science and maths compare poorly with our competitor nations, such as Germany, Finland, and Japan[2].

5. Consequently, it is essential that the Government places a greater emphasis on improving practical skills in schools in order to support the economic recovery, but also to support a rebalancing of the economy towards STEM sectors and away from an over-reliance on the financial services sector.

6. CaSE therefore supports the evidence given to the Committee by the Standing Committee Representing Education (SCORE), and we would make the following additional points.

7. Training and subject-specific continuing professional development (CPD) for teachers is crucial for improving the quality of teaching in schools. CPD was one of the areas covered by CaSE's analysis of the Education White Paper, sent to the Secretary of State for Education on 10th February[3]. CaSE received no adequate response to this analysis, and is concerned that the department is ignoring the science and engineering community's concerns[4].

8. A further issue is that although practical and lab-based skills need to be improved generally, the problem is even more acute in inner-city and state schools. Figures show that independent school pupils tend to be over-represented in A-level entries for STEM subjects[5]. Moreover, opportunities for fieldwork are skewed to the independent sector, the decline in A-level Biology fieldwork has been more marked in state schools, and that there are few planned opportunities for science fieldwork at

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[1] *Building for Growth: business priorities for education and skills*, CBI, May 2011
[2] *Science, Engineering & the Devolved Nations*, CaSE, April 2011
[3] *Letter to Michael Gove – Education*, CaSE (published online), February 2011.
[4] *Businesses concerned by school leavers' skills*, the Financial Times, May 2011
[5] *Full A-level results briefing*, JCQ, 2010.

Key Stages 3 and 4 in inner-city schools[6]. The Government should place a special emphasis on combating this unfairness.

9. We also highlight the particular issues faced in computer science and IT. Practical skills in these subjects are essential for navigating the modern world, while an advanced understanding of such skills is critical for the UK's growing technology-based economy. Despite this, the BCS (Chartered Institute for IT) note that computing teaching in the UK is "on the verge of collapse"[7]. Further, Ofsted note that much teaching focuses on teaching students how to use specific items of software, rather than an understanding of what computer science is[8]. A practical understanding of computer science should form a more central part of the pupil experience in schools.

Declaration of Interests

The BCS (Chartered Institute for IT), and three of SCORE's five members (the Society of Biology, the Royal Society of Chemistry, and the Institute of Physics), are organisational members of CaSE.

Imran Khan
Director
Campaign for Science and Engineering

11 May 2011

[6] *Outdoor Science*, the Association for Science Education 'Outdoor Science Working Group', 2011
[7] *The Collapse of Computing Education in English Schools*, CaSE Blog, 2011
[8] *The Importance of ICT*, Ofsted, 2009

Written evidence submitted by The Science Council (Sch Sci 38)

Background

The Science Council is an umbrella organisation of over 30 learned societies and professional bodies in the UK[1] drawn from across science and its applications: a list of member organisations is attached. In addition to providing a mechanism for the sector to work collectively, the Science Council develops and leads collaborative projects working with member bodies and the wider community, including the Future Morph web site that is designed to provide information for young people, their parents and teachers about careers from studying science and mathematics. The Science Council awards the professional qualification of Chartered Scientist (CSci) and is now leading an initiative which aims to raise the profile and aspirations of technician and graduate scientists by developing new professional registers at these levels. Collectively our member bodies represent more than 350,000 individual members, including scientists, teachers and senior executives in industry, academia and the public sector.

The Science Council has a keen interest in enhancing the level and quality of science education, knowledge and skills in the UK and welcomes the opportunity to contribute to this inquiry. The Science Council's strength comes from its multi-disciplinarity, enabling us to draw from the breadth of science and types of scientists in responding to complex issues in science and education.

Key Points

1. Practical work plays a key role in enhancing understanding and improving engagement
2. The practical and technical are skills integral to science and vital for science employers
3. Practical activities and field work provide a valuable real life context for multi-disciplinary learning
4. Hands on experience of science can help young people develop their career preferences
5. Enhancement and enrichment activities can help provide additional opportunities for practical work

Understanding and awareness of the breadth of science

Practical enquiry provides the opportunity to develop knowledge and understanding of key concepts in science and this is central to all teaching and learning in science. In addition to facilitating awareness of science in practice, practical experiments and field work can provide an excellent opportunity to show how biology, chemistry and physics interact, the connection to other sciences and the multidisciplinary nature of science. The major challenges facing the world, for example, food security, climate change and water scarcity will demand a multi-

[1] Appendix 1 List of Science Council Member Organisations

disciplinary approach to seek solutions. In addition a host of new areas promising future innovation, such as bioengineering or biophysical chemistry, require an interdisciplinary approach that combines fields. Learning outside the classroom yields valuable real life examples of the interplay between science disciplines; teachers need to be supported and resourced to make the most of these opportunities.

Future scientists

Experimentation is of central importance to the practice of science and it is hard to imagine a quality school education in the subject which does not incorporate experience of practical experiments for all learners. The inclusion of practical work is of particular importance for those learners who may consider a future working in science as there is widespread concern amongst science employers with regard to a lack of practical and technical skills at all levels, including graduates. The Science Council recognises that this is an important issue in the education and training of professionals in science at all levels. This is illustrated by the view of the Institute of Biomedical Science:

> "The development of practical skills based on interactive teaching of the core sciences is key to the assimilation of technological advances."

The UK's growing economic need for a workforce with science skills includes a demand for those utilising technical and practical skills at technician level with the UKCES Working Futures report[2] identifying that the number of associate scientific and technical professionals is set to rise by 6.5% between 2007 and 2017. Practical and field work play a key role in helping to raise awareness of the value of technical skills and the employment settings in which they can be applied.

Enjoyment and engagement

Practical and investigative work can enhance engagement in science and be a motivating and effective style of teaching and learning. NESTA's 2005 Real Science report looked at the value of science enquiry, which often involves practical work, and stated;

"The potential of science enquiry to engage and motivate learners is clear from the outcomes from NESTA projects, those projects funded and supported by other organisations, and from the broader research literature."[3]

Attainment alone will not attract increased numbers of young people to science, therefore, it is important that there is opportunity and imperative for teachers to utilise practical work in the classroom.[4] Research studies[5] [6] have shown that there is lack of connection between young people enjoying science and visualising a future for themselves as a scientist. Practical experiments can enable young people to experience a taster of the processes employed by scientists in their work and assess their enjoyment of such activities.

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[2] UKCES (2009) Working Futures 2007-2017
[3] NESTA 2005 Real Science http://www.nesta.org.uk/publications/assets/features/real_science
[4] SCORE 2010 Practical Work in Science http://www.score-education.org/policy/wider-learning-experience/practical-work-in-science
[5] Edgar, Nelson Important but not for me 2005
[6] Public Attitudes to Science, Ipsos Mori, Dept. for Business, Innovation & Skills 2011

Support for practical work

Many of the Science Council member organisations seek to ensure that practical work is of high quality by providing a wide range of support for teachers through provision of resources, support for the delivery of projects and activities, continuing professional development and support networks. The Institute of Physics, Royal Society of Chemistry and Society of Biology all support websites making available examples of high quality practical activities[7] and offer CPD courses. The Society for General Microbiology[8] and Royal Society of Chemistry have both looked at safety issues and provide guidance to alleviate teachers' concerns and illustrate techniques. A more detailed list of some of this work can be found in Appendix 1. The extensive work undertaken can only be effective if teachers know how to access the assistance and have time and resources to do so: this is obviously an area where the Department for Education can assist.

There are a wealth of hands on science enhancement and enrichment initiatives, including many delivered by our member organisations and partners, whose evaluation has shown that such activities can raise the aspiration and engagement of young people. Many of these take place outside of school, one such activity is the annual Big Bang: UK Young Scientists and Engineers Fair, led by Engineering UK. The evaluation for the 2010 event[9] shows increased understanding, enjoyment and awareness of career options for science and engineering. The Government funded after school STEM Clubs provide a further opportunity for practical experience and the evaluation of the precursor scheme[10] provides evidence of increased enjoyment and aspirations to become a scientist or engineer.

As a former member of SCORE[11] the Science Council supports its detailed work on the issue of practical work in science education. SCORE is currently undertaking research to explore the resourcing requirements of practical laboratory and field work, including laboratory facilities, consumables, equipment and technician time. This work will help to inform the evidence base for policy matters on the factors that enable good quality practical work.

The Science Council

11th May 2011

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7 www.practicalphysics.org, www.practicalchemistry.org, www.practicalbiology.org
8 http://www.microbiologyonline.org.uk/teachers/safety-information,
9 http://www.thebigbangfair.co.uk/_db/_documents/The_Big_Bang_2010_Evaluation_Summary.pdf
10 After-school Science and Engineering Clubs Evaluation, DCSF Oct 2008
11 Association for Science Education, Institute of Physics, Royal Society, Royal Society of Chemistry, Society of Biology http://www.score-education.org

Appendix 1

Some examples of the ways in which Science Council Member Organisations support practical work

Association for Science Education

The Association for Science Education has been a strong voice in promoting excellent practical work to support science education from its inception in 1901. More recently, our efforts have focused on the Department for Education funded "Getting Practical" project which incorporated research into professional development and made real progress in improving practice. We believe that authentic practical experiences in science are essential to engagement with the subject. From our members we understand that support for practical science in schools is currently in some difficulty. We have concerns about the provision of school laboratory technicians (many of whom are members of ASE), about laboratory design and about sufficient emphasis during initial teacher education on the management of practical lessons.

Getting Practical www.gettingpractical.org.uk
A programme of professional development designed to support teachers, technicians and high level teaching assistants at primary, secondary and post 16 levels consider the way in which they teach practical science with a view to improving the quality of their teaching.

The programme aims to improve the:
- Clarity of the learning outcomes associated with practical work.
- Effectiveness and impact of the practical work.
- Sustainability of this approach for ongoing improvements.
- Quality rather than quantity of practical work used.

Bringing together these aims will develop a teacher's ability to assess the way they teach practical science at all levels and increase their confidence in producing good quality lessons for the benefit of the learner.

Geological Society

Code for Geological Fieldwork http://www.geolsoc.org.uk/page2542.html

Gower Field Guide http://www.geolsoc.org.uk/gsl/education/resources/page2544.html

A field guide to the solid geology of the Gower Peninsula.

Institute of Materials, Mineral and Mining

Schools Affiliate Scheme – Connecting teachers to the world of materials, minerals and mining http://www.iom3.org/sas

Membership of the Scheme allows access a range of resources which will support and enhance teaching. Contained within the site there is information to help bring the materials, minerals and mining topics in the 11 to 19 curriculum to life. Previous newsletters and support literature can be downloaded, and in the near future it will be possible to gain access to the presentations given at the Institute's conferences for teaches and find out about how to borrow one of the Institute's resource loan boxes.

Institute of Food Science and Technology

Ideas for lesson plans http://www.ifst.org/learninghome/helpforteachers/
These lesson plans include ideas for practical work on topics including Cereals, Supply Chain Management, Milk, Fruit & Vegetables and Food Texture

Institute of Physics

The Model Project: The resource provides ideas for practical physics activities, student instructions and worksheets plus guidance for teacher and technicians. The practical activities are supported by video sequences showing how some people use physics in the jobs they do. The activities were designed for 14-16 year olds and the resource includes links to the relevant UK specifications. See: http://www.iop.org/education/teacher/resources/model/page_41554.html

Practical Physics website. The website includes notes on apparatus, procedure, and teaching notes, together with general guidance on teaching approaches. See: http://www.practicalphysics.org/

General CPD support, for example, supporting for non specialists through the Stimulating Physics Network to with guidance for teachers and technicians on setting up and using apparatus.

Videos on practical work available through talkphysics website and the National STEM Centre site (see: http://www.nationalstemcentre.org.uk/elibrary/search?term=videos+institute+of+physics)

Institution of Chemical Engineers

12 exciting hands-on experiments
http://www.whynotchemeng.com/uk-and-ireland/teachers/teacher-resources-/key-stage-2-and-3-resources

12 exciting hands-on experiments, developed by Dr Mark Biddiss, are designed to be safely used in the classroom. Each experiment is accompanied by instructions, shopping list and useful information, and are taken from Dr Mark's Magical Science 1 & 2 Books and CD Roms.

Water Boxes
Since 2004, IChemE's Water Subject Group have been donating a limited number of 'water boxes' to schools both in the UK and overseas. The boxes contain 21 water-based experiments and are currently supplied by Three Valleys Water.

Royal Astronmical Society

The RAS offers support for the teaching of astronomy and geophysics in schools in a variety of ways, from putting teachers in touch with astronomers who can assist with practical outreach to managing the legacy of the ‘Telescopes for Schools’ project which gave telescopes to 1000 schools during the International Year of Astronomy in 2009. Simple equipment such as a pair of binoculars or one of these 1000 small telescopes is enough to see many celestial objects, from craters on the Moon to the clouds of gas and dust where stars form.
http://www.ras.org.uk/education-and-careers/for-schools-and-teachers

Royal Meteorological Society

MetLink Website http://www.metlink.org/

MetLink is an educational website of the Society with weather and climate resources aimed at primary and secondary school teachers, students, teenagers, children and the general public. Resources include lesson plans, experiments and demonstrations and after school club activities.

Royal Society of Chemistry

11+ Resources
Practical Chemistry Website http://www.practicalchemistry.org/
This website provides all teachers of chemistry with a wide range of experiments to illustrate concepts or processes, as starting-points for investigations and for enhancement activities such as club or open day events.

Video Clips
http://www.rsc.org/Education/Teachers/Resources/Practical-Chemistry/video-clips/index.asp

Downloadable clips produced by Teachers TV in association with the RSC. This material was sent to schools in the Autumn of 2006 on a DVD.

Demonstration Videos
http://www.rsc.org/Education/Teachers/Resources/Practical-Chemistry/Videos/index.asp

The RSC commissioned a series of video demonstrations providing guidance for some fundamental, and some very exciting, reactions. Accompanying notes from Classic Chemistry Demonstrations are provided for the demonstration videos.

Making Measurements and Manipulating Experimental Results
http://www.rsc.org/Education/Teachers/Resources/Practical-Chemistry/Experimental.asp

This online resource provides a clear and concise summary of a topic that both teachers and students often find confusing.

Investigate Chemistry
http://www.rsc.org/Education/Teachers/Resources/InvestigateChemistry.asp
In 2009 the Royal Society of Edinburgh and the Royal Society of Chemistry recognised a need for exemplification of the Chemistry "experiences and outcomes" in a Curriculum for Excellence. Through this project three resource packs were created. The resources have been designed in line with the Scottish Curriculum for Excellence but could be easily adapted for teaching elsewhere.

16+
Discover LabSkills
http://www.rsc.org/Education/DiscoverChemistry/DiscoverLabSkills.asp
The Discover LabSkills Project was launched in January 2009 through collaboration of the RSC / Pfizer education programme, Discover Chemistry, with the University of Bristol and Learning Science Ltd.
The aim of the project was to improve access to the LabSkills Dynamic Lab Manual (DLM) to allow teachers and student to develop and improve their practical laboratory skills.

Practical Chemistry for Schools and Colleges
http://www.rsc.org/Education/Teachers/Resources/practical/index3.htm
Video footage of standard experimental techniques including assembling apparatus.

Chemistry for Non Specialists
(http://www.rsc.org/Education/Teachers/CPD/ChemNonSpec/index.asp)

Society for General Microbiology

Basic Practical Microbiology for Secondary Schools - Accredited one day course for secondary school teachers, technicians and PGCE science students providing basic training in the techniques needed to carry out interesting microbiology investigations safely in schools.

Advanced Practical Microbiology for Secondary Schools – Measuring microbial growth
One-day, practical based course for secondary teachers and technicians deals with a variety of suitable methods.

Basic Practical Microbiology: A Manual
Manual for teachers and technicians explaining basic techniques necessary to carry out microbiology experiments safely and effectively.

Practical Microbiology for Secondary Schools
21 safe practical investigations suitable for KS3 & 4/GCSE and equivalent Scottish qualifications. Many of the experiments also meet the needs of the AS/A2 specifications and can be adapted for project work.

Online safety/ practical information: http://www.microbiologyonline.org.uk/teachers

Video portal streaming practical techniques: http://www.microbiologyonline.org.uk/what-s-hot/podcasts-and-vodcasts

Society of Biology

Practical Biology
http://www.practicalbiology.org/

Practical Biology provides teachers of biology at all levels with experiments that demonstrate a wide range of biological concepts and processes. Each practical may be used alone or as a starting-point for open-ended investigations or enhancement activities, such as clubs or open-day events. Experiments are placed within real-life contexts, with links to carefully selected further reading, enabling teachers to show relevance and illustrate the key principles of How Science Works.

Society of Dyers and Colourists

The **Colour Experience** includes a range of supported activities to introduce young people to hands on experiences with colour.
http://www.sdc.org.uk/en/education/colour-experience/index.cfm

Appendix 2
Science Council member organisations

March 2011

1. Association for Clinical Biochemistry*
2. Association of Neurophysiological Scientists
3. Association for Science Education**
4. British Computer Society*
5. British Psychological Society*
6. Chartered Institution of Water and Environmental Management*
7. Energy Institute*
8. Geological Society of London*
9. Institute of Biomedical Science*
10. Institute of Brewing and Distilling
11. Institute of Clinical Research*
12. Institute of Corrosion*
13. Institute of Food Science and Technology*
14. Institute of Marine Engineering, Science and Technology*
15. Institute of Materials, Minerals and Mining*
16. Institute of Mathematics and its Applications*
17. Institute of Physics and Engineering in Medicine*
18. Institute of Physics*
19. Institute of Professional Soil Scientists*
20. Institution of Chemical Engineers*
21. Institution of Environmental Sciences
22. London Mathematical Society
23. Mineralogical Society
24. Nuclear Institute*
25. Oil and Colour Chemists' Association*
26. Royal Astronomical Society

27. Royal Meteorological Society
28. Royal Society of Chemistry*
29. Royal Statistical Society
30. Society for General Microbiology
31. Society of Biology
32. Society for Cardiological Science and Technology
33. Society of Dyers & Colourists

* Licensed to award Chartered Scientist – CSci
** Licensed to award Chartered Science Teacher - CSciTeach

Written evidence submitted by The Association for Science Education Outdoor Science Working Group (Sch Sci 39)

The **Association for Science Education (ASE)** is the largest subject association in the UK. Members include teachers, technicians and others involved in science education. The Association plays a significant role in promoting excellence in teaching and learning of 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 ideas and tackle challenges in science teaching, develop resources and foster high quality Continuing Professional Development. The Association for Science Education can trace its origins back to 1900. Incorporated by Royal Charter in October 2004, the ASE operates as a Registered Charity.

The **Outdoor Science Working Group (OSWG)** was convened by ASE in 2004 in response to a long and continuing decline in the use of outdoor fieldwork to teach science in the UK's schools, particularly at secondary level. The OSWG feels that this is detrimental to the quality of science education and reduces the opportunities for children to appreciate everything that science has to offer them, both as future citizens and potential recruits to science careers. The ASE OSWG is chaired by ASE, and includes representatives from university science education departments including King's College London, Keele, Birmingham and Southampton, and science education bodies such as Field Studies Council (FSC), Science and Plants in Schools (SAPS) and British Ecological Society (BES).

1. This response is submitted in addition to the SCORE response covering practical work and fieldwork in science, to which ASE contributed as a member organisation of SCORE.

2. This response focuses on fieldwork aspects and draws on two reports from ASE's OSWG in 2011[1] and 2007[2]. This response is informed by evidence from members of ASE's OSWG and their organisations together with an ASE survey of science teachers and others involved in science education. The survey evidence presented here is a summary of responses from 388 teachers who contributed to an online survey carried out by ASE in 2011[3]. 90% of respondents were secondary school teachers in England, with subject teaching equally divided across science disciplines (35% Physics; 33% Chemistry; 32% Biology).These data have not been published previously.

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[1] Outdoor Science Working Group (2011). *Outdoor Science. A co-ordinated approach to high-quality teaching and learning in fieldwork for science education*. Association for Science Education/Nuffield Foundation. Field Studies Council Occasional Publication 144.

[2] Outdoor Science Working Group (2007). *Initial Teacher Education and the Outdoor Classroom: Standards for the Future*. Field Studies Council and Association for Science Education. Field Studies Council Occasional Publication 122.

[3] ASE survey of teachers on practical work and field work, 388 responses including smaller numbers of responses on specific fieldwork questions (April 2011)

Are science field trips in decline? If they are, what are the reasons for the decline?

3. The survey data indicates there is a huge range in provision between schools, ranging from regular trips for most years to none at all. Whereas most teachers (67%) thought that the level of provision had remained the same as previous years, a significant minority (29%) felt that it had declined. Only 4% thought that it had increased. Stated reasons for the decline included inadequate time available for planning and taking students out of classroom, disruption to school timetables and increasingly, a lack of funding.

4. Elsewhere, there is strong evidence from a variety of sources including a survey in 2010 indicating a decline in the number and duration of biological fieldtrips over the past 40 years.[4]

5. The survey data indicates that 33% of respondents feel inexperience of teachers in carrying out practical work is an issue and 22% indicated that they would welcome more professional development opportunities to develop their confidence with practical work. ASE's OSWG has consistently identified that there is a shortage of secondary science teachers with the confidence, competence and commitment to lead fieldwork. In response, the ASE OSWG has released two reports[5] which have made recommendations to remedy this shortage.

How important are field trips in science education?

6. Over two thirds (68.3%) of teachers feel that field trips are important or very important. Table 1 summarises the overall responses.

	Secondary	**Primary**
	n=199	**n=11**
Very Important	29.1%	0.0%
Important	39.2%	81.8%
Mildly Important	22.6%	18.2%
Not Important	4.0%	0.0%

Table 1. 2011 ASE teachers' survey. How important are field trips in science education?

[4] Lock, R. (2010). Biology fieldwork in schools and colleges in the UK: an analysis of empirical research from 1963-2009*. Journal for Biological Education* 2: 58-34

[5] Outdoor Science Working Group (2011). *Outdoor Science. A co-ordinated approach to high-quality teaching and learning in fieldwork for science education*. Association for Science Education/Nuffield Foundation. Field Studies Council Occasional Publication 144.
Outdoor Science Working Group (2007). *Initial Teacher Education and the Outdoor Classroom: Standards for the Future*. Field Studies Council and Association for Science Education. Field Studies Council Occasional Publication 122.

7. The importance of field trips is also evidenced both through the level of activity (see Figure 1) that is going on, but also the strength of accompanying statements.

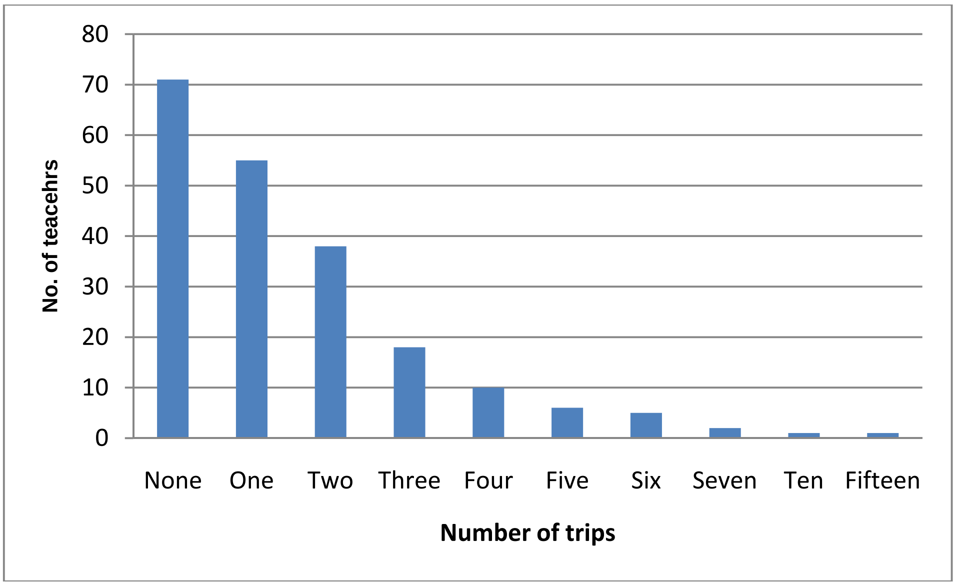

Figure 1. ASE 2011 survey. How many field trips have you undertaken or intend to carry out in the 2010/2011 academic year?

Exemplar statements

8. "My fondest memories of my A level course were the field trips and they formed my desire for science and to teach. They are about seeing science in context and not in theory, whether it is seaweed on a rocky shore, fossils in a quarry or the Haber process in a chemical plant. Good field trips are more than discovery; they are also about teamwork, leadership and other personal skills."

9. "Field trips show that science is for real and not just something that is done at school. They give a greater understanding of the world of science. They can help generate more interest and can help spark the less interested students. They can show students a possible way forward for careers. They can help students understand the real world around them."

10. "Out of classroom science enables pupils to understand the complexity of the real world and how it can be investigated. It provides opportunities for learning how to observe, raise questions, investigate in contexts where there is often not a 'right answer' and deal with 'messy' data (data that shows variation and therefore consideration needs to be given as to its quality). Many real world issues involve such 'messy' data - it is important that students learn that evidence is seldom as clear cut as in a contrived lab-based experiment. Uncertainty in data is inevitable and students need to learn that this is inherent in science and not the fault of the scientists 'doing it wrong'."

11. "Field trips allow pupils to experience environments and activities that they may not otherwise have access to (due to socio-economic factors, location, etc). Field trips encourage pupils to develop an appreciation of the environment and the need for environmental conservation and sustainability. Field trips to museums and

workplaces allow pupils to learn about science in context and provide future opportunities for STEM careers."

12. The survey data indicates that field trips involve all age phases (activity as a proportion of total secondary school field trips are shown in brackets below), but also notes with concern that barriers are most pronounced at GCSE (Key Stage 4) level:

- Key Stage 3 (34%)
- Key Stage 4 (22%)
- A level, 16-19 (46%)

13. Field trips can occur at any time of the academic year (activity as a proportion of total secondary school field trips are shown in brackets below), but most activity is disproportionately placed in the post exam period in Summer Term, mainly because of exam and timetabling constraints, and the increased availability of cover staff.

- Autumn Term (17%)
- Spring term (16%)
- Summer Term (67%)

14. A wide range of sites and activities are being used by UK teachers, which include (in declining order, with number of references in brackets):

- Ecology sites/local habitats (including school grounds) (63)
- Field Centres (28)
- Museums (21)
- Wildlife park/zoos (19)
- Science/technology centres (19)
- Space centres (incl. CERN) (16)
- Universities (15)
- Industry (16)
- Farms (8)
- Botanical gardens (5)

Others (<5) included: hospitals, powers stations, theme parks, research labs, mines and quarries, aquaria, reservoir, army barracks and a recycling plant.

What part do health and safety concerns play in preventing school pupils from going on field trips? What rules and regulations apply to field trips and how are they being interpreted?

16. Table 2 below summarises the responses of teachers to the barriers to practical work. It is likely that health and safety concerns will be more prominent when considering field trips and these undoubtedly act as a deterrent. However, a large number of written responses identified the administration and paperwork – including the need to find and fund staff cover - as the main obstacles, rather than the health and safety risks themselves.

How much of a barrier do you consider these issues to be when deciding whether to carry out practical work in science at your school?				
	Greatest Barrier	**Less of a Barrier**	**Not a Barrier**	**Response counts**
Resources and facilities	36.6% (111)	41.3% (125)	22.1% (67)	303
Teachers' inexperience	32.6% (99)	41.4% (126)	26.0% (79)	304
Health and safety	15.8% (48)	53.3% (162)	30.9% (94)	304
Technical support	21.8% (66)	45.2% (137)	33.0% (100)	303
Exams and assessment	45.2% (137)	38.3% (116)	16.5% (50)	303
Pupils' behaviour	37.9% (114)	43.2% (130)	18.9% (57)	301
Curriculum (content and resources)	38.5% (116)	49.5% (149)	12.0% (36)	301
Time	52.1% (158)	37.3% (113)	10.6% (32)	303
CPD Provision	15.9% (47)	52.2% (154)	31.9% (94)	295
				Answered question 306
				Skipped question 82
				Others please specify 31

Table 2 ASE survey 2011

17. ASE's OSWG welcomes many of the findings of Lord Young's Review[6] and his proposals to simplify the process that schools and other organisations undertake before taking children on outdoor learning experiences.

Do examination boards adequately recognise science field trips?

18. The survey data indicates that nearly three quarters (71%) of the teachers who expressed an opinion (Yes or No, n=160) felt that examination boards did not adequately recognise the work carried out on field trips (71%, n=160). It was noted that some awarding organisations had stronger recommendations than others. Some commented that a stronger recommendation would support a greater take up of field trips.

19. Elsewhere evidence links the amount of fieldwork to curriculum and assessment. Fieldwork has not been compulsory in the national curriculum for science, unlike geography. As a result, geography numbers have grown for the Field Studies Council courses over 20 years, replacing science as the major contributing subject to Field Studies Council visitor numbers. Geography teachers are twice as likely to do residential fieldwork at Key Stage 3, and ten times more likely at GCSE level; they were also twice as likely to do local fieldwork at both levels.[7]

If the quality or number of field trips is declining, what are the consequences for science education and career choices? For example, what effects are there on the performance and achievement of pupils and students in Higher Education?

20. The OSWG believes that a continuing decline in field trips will lead to a downward spiral in provision. For example, an increasing the number of science graduates who lack prior experience in fieldwork will reduce the number of trainee

[6] Common Sense; Common Safety (2010) http://www.number10.gov.uk/wp-content/uploads/402906_CommonSense_acc.pdf
[7] Tilling, S. (2004). Fieldwork in UK secondary schools: influences and provision. *Journal of Biological Education* 38 (2): 54-58.

and early career science teachers with the confidence, competence and commitment to teach fieldwork themselves.

21. A reduction in field trips will affect the quality of science education – for example weakening the opportunities to observe and practice the learning of science in the context of the 'real world', reducing the chances of a wider range of learners to fulfill their potential and weakening the development of critical skills such as data handling and analysis. The main sources of inspiration and motivation for some students will disappear, thus reducing potential recruitment to the UK's science knowledge base.

22. This is of particular concern with the pressing need to address the world's major environmental challenges. It is noted that the UKCES4 report[8] highlights the areas of conservation and environmental protection as being one of the biggest growth areas in terms of employment over the last 10 years. By 2020, approximately 4% of the work force will be involved in 'green jobs' in a variety of capacities with education standards including level 2-4 and beyond 5; many of which will include elements of fieldwork. Similarly, the NERC funded ERFF report 7[9] highlights fieldwork as being one of it's ten most wanted skills required for the next ten years, highlighting a decline in the knowledge base in this area.

What changes should be made?

23. The evidence from this research and earlier ASE OSWG-hosted national workshops points to the wide-ranging educational benefits of teaching and learning science through fieldwork in the natural and built environments. These benefits are widely recognised;[10] yet despite the strengths and advantages that fieldwork can bring to teaching at all ages, there has been a decline in the provision and condition of outdoor education in science. ASE's OSWG believes that this trend is detrimental to science education.

24. The recommendations below will provide a strong foundation for a shared and coherent approach towards increased uptake and improved quality of teaching and learning through fieldwork in science education.

Recommendation 1

Reviews of initial teacher training, Qualified Teacher Status standards and continuing professional development such as the current independent review of qualifications to raise the standards of teaching, led by Sally Coates, must ensure that fieldwork training is expected and provided for all trainee science teachers. **All trainee science teachers should be expected to prepare and lead at least one fieldwork session themselves, and to take part in a fieldwork trip.** A co-coordinated programme of teacher training in fieldwork should therefore be

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[8] Skills for Jobs: Today and Tomorrow (2010) http://www.ukces.org.uk/upload/pdf/NSSA_Volume%201_FINAL_BOOKMARKED_110310.pdf

[9] Most Wanted Postgraduate Skills Needs in the Environment Sector http://www.nerc.ac.uk/funding/available/postgrad/skillsreview/summary.pdf

[10] Dierking, L. *et al.* (2003) Policy statement of the "informal science education" ad hoc committee
House of Commons Education and Skills Committee (2005) *Education outside the classroom*
Department for Education and Skills (DfES) (2006) *Learning outside the classroom manifesto*
House of Commons Children, Schools and Families Committee (2010) *Transforming education outside the classroom*
Ofsted (2010) *Science Survey Visits*. Generic grade descriptors and supplementary subject-specific guidance for inspectors on making judgements during visits to schools

established to promote effective pedagogy for all university tutors and school teachers involved in pre-service and early career training.

Recommendation 2
A dedicated outdoor science web-site, aimed at teachers, technicians and outdoor educators, should be created to signpost, exchange and compare high-quality fieldwork training resources. The website should encompass local and context-specific support and include contacts for expert advisers, local support networks, existing good practice, training events and fieldwork providers as well as published materials.

Recommendation 3
Performance management and designations (for example, to AST or Excellent Teacher level) should include **an opportunity for early-career teachers to demonstrate their effective use of fieldwork** and for more experienced teachers to demonstrate their own role in providing fieldwork training for colleagues in other departments and schools (including across age phases and transitions).

Recommendation 4
Awarding bodies should be provided with the flexibility and support to **significantly increase open-ended summative assessment** and assessments that recognise skills which are primarily developed through fieldwork.

Recommendation 5
A coordinated research programme should be developed to further investigate the full range of educational impacts of fieldwork in science including case studies in formal/ informal contexts, day/residential venues, local/remote sites and rural/urban communities.

Recommendation 6
Leading educational bodies, learned societies and high-profile supporters of outdoor education should use their combined influence to **support positive attitudes towards fieldwork in science** amongst their contacts and audiences (including headteachers, governors and parents). These institutions and individuals should focus particularly on areas such as raising the profile of fieldwork in whole school policies and development plans, a reduction in health and safety bureaucracy and the development of in-service professional development programmes.

Marianne Cutler
ASE Director of Curriculum Innovation and Chair of ASE's OSWG
Association for Science Education Outdoor Science Working Group

10 May 2011

Written evidence submitted by NASUWT (Sch Sci 40)

The NASUWT's submission sets out the Union's views on the key issues identified by the Committee in the terms of reference for the inquiry and is based upon the work of its representative committees and other structures, made up of practising teachers and lecturers working in all relevant sectors of the education system.

The NASUWT is the largest union representing teachers and headteachers in the UK, with over 280,000 serving teacher and school-leader members.

Executive Summary

- The NASUWT notes with concern the citation by the Committee of press reports that the number of practical experiments in science lessons in schools and science field trips may be in decline.
- The Union is aware of no credible evidence that this is in fact the case and is clear that the press reports to which the Committee appears to refer seek to advance an argument that provisions in relation to health and safety are militating against schools undertaking activities of this nature.
- Learning outside the classroom can provide valuable educational experiences and curriculum enrichment, providing it is planned, properly resourced, linked to the curriculum and has clearly identified intended learning outcomes.
- While the Coalition Government has confirmed that science will remain a compulsory element of the curriculum for pupils in the 5-16 age phase, its programme of reforms place current curricular entitlements to learning outside the classroom and practical activities at risk.
- The lack of any requirement on academies and free schools to offer learning outside the classroom or practical science-related learning guaranteed in other schools currently through the provisions of the National Curriculum, could deny pupils in these schools the chance to benefit from these activities.

- Cuts in school and local authority budgets are likely to lead to pressures on schools to limit pupils' access to learning outside the classroom or to practical activities in science, based on their relatively high cost, as well as increased financial demands being made of parents.
- It is essential that processes and procedures put in place in respect of health and safety in schools and local authorities allow the health and safety of all those participating in or overseeing learning outside the classroom or practical activities to be managed effectively.
- Schools should be encouraged to make use of quality assurance arrangements that support the delivery of learning outside the classroom, including providers that are pre-approved, thereby reducing costs and associated bureaucracy.

Background and context

1. The NASUWT welcomes the opportunity to submit evidence to the Science and Technology Committee inquiry into school science lessons and science field trips. The range of issues highlighted in the terms of reference of the inquiry highlight four fundamental areas of concern:
    - the extent to which the curriculum and qualifications framework promote the use of learning outside the classroom and practical learning in science;
    - the impact of the Coalition Government's drive to expand significantly the number of academies and free schools within the state-funded education system;
    - the implications of real-terms reductions in education-related expenditure; and
    - the health and safety context within which learning outside the classroom and practical activities take place.

2. Each of these considerations is explored in more detail below. However, at the outset, the NASUWT must raise its concerns about the citation by the Committee of press reports that the number of practical experiments in science lessons in schools and science field trips may be in decline. The Union is aware of no credible evidence that this is, in fact, the case and notes with concern that the press reports to which the Committee appears to refer seek to advance an

argument that provisions in relation to health and safety are militating against schools undertaking activities of this nature. The NASUWT takes the view that reports of this nature are being advanced as part of an ill-considered and unsustainable attempt to discredit the existing framework of health and safety law and regulation applicable to schools.

3. While the NASUWT recognises fully the right of the Committee to consider issues relating to learning outside the classroom and the use of experiments in pupils' science learning experiences, the Union recommends that the Committee ensures that it takes forward its work in this area on the basis of valid and reliable evidence rather than partial reporting in some sections of the media.

The role of the curriculum, qualifications and school accountability framework

4. The NASUWT believes that all pupils are entitled to access a broad and balanced curriculum. In particular, the curriculum should recognise different forms of learning, including academic and practical learning, and offer rich, engaging and relevant learning experiences. Not only is this a fundamental right of all children and young people, it is also critical to tackling disaffection, addressing poor pupil behaviour and ensuring that learning objectives for pupils with special educational needs or who are gifted and talented are secured effectively. The curriculum should help learners to become confident and successful and enable them to make a positive contribution to society.

5. The NASUWT recognises that learning outside the classroom can provide valuable educational experience and curriculum enrichment, providing it is planned, properly resourced, linked to the curriculum and has clearly identified intended learning outcomes. Learning outside the classroom activities can enable pupils to be more engaged and enthusiastic learners and can provide an important means by which key learning objectives in relation to science can be secured for pupils.

6. Equally, the provision of an effective science curriculum requires pupils to be given opportunities to engage in practical experiments and activities in order to extend and consolidate their understanding of key concepts and principles.

7. The importance of learning outside the classroom and of practical activities in science is reflected in the provisions of the statutory programmes of study for the subject set out in the National Curriculum. This curricular framework serves as a common learning entitlement for all pupils in all schools and thereby ensures that pupils' learning in science incorporates effective use of opportunities to learn outside the classroom and to undertake practical activities to support and consolidate their learning.

8. The Committee will therefore be concerned by proposals set out in the education White Paper, *The Importance of Teaching,* for future reform of the curriculum. While the White Paper confirms that science will remain a compulsory element of the curriculum for pupils in the 5-16 age phase, it intends to revise the content of the curriculum so that it is more focused on knowledge rather than skills. Developed on this basis, the entitlement to learning outside the classroom and practical activities set out in the current curriculum may be marginalised.

9. While it is clear that in seeking the best possible learning outcomes for pupils, teachers recognise fully that learning outside the classroom and practical activities are essential elements of a rounded and engaging science experience, the potential removal of curricular entitlements in this regard could result in greater pressures being placed on teachers to focus, to a disproportionate extent, on knowledge-related areas of learning rather than the practical application of this knowledge.

10. The implications of the school accountability regime are a critical consideration in this regard. The Coalition Government has made clear that it intends to intensify the use of performance tables and other data-related means of holding schools to account, while proposals being taken forward in relation to the reform of the school inspection regime make clear that this will rely to an even greater extent on performance data in the formation of judgements about school performance

by inspectors. The potential negative consequences of perceived failure by schools in terms of their performance data and inspection outcomes will become even more pronounced as a result of the Coalition Government's proposals for school accountability as set out in the White Paper. In a context where curricular guarantees in relation to learning outside the classroom and practical experiences are diminished, restrictive teaching and learning approaches which seek merely to secure the best possible performance data outcomes are likely to be incentivised to an inappropriate extent. The Committee will therefore wish to consider in more detail the potential implications of curricular reform and the impact of the school accountability regime on the ability of schools to ensure that learning outside the classroom and practical learning in science plays an effective part in the science learning offer available in schools.

11. The Committee is right to highlight the importance of the qualifications structure in the promotion of learning outside the classroom and the use of practical experiments in science learning. Currently, specifications for science-related GCSEs and A-levels set out clear requirements in relation to field trips and practical learning. However, it should be recognised that the inclusion of such activities in specifications is not a discretionary matter for awarding bodies but is instead a requirement for the accreditation of these qualifications by the Office of Qualifications and Examination Regulation (Ofqual).

12. Currently, a key function of Ofqual in establishing these requirements is that they are consistent, where applicable, with the requirements of the statutory National Curriculum. Given the specific reference to learning outside the classroom and practical activities in the science National Curriculum, it is therefore appropriate that they are included within GCSE and A-level specifications. However, any removal of these requirements from the National Curriculum that may result from the reforms being taken forward by the Coalition Government could therefore leave open the possibility that they could also be removed from the accreditation requirements set out by Ofqual.

13. In addition, the decision by the Coalition Government to allow state-funded schools to offer the International GCSE (IGCSE) as a Level 2 qualification should

also be regarded by the Committee as a matter of concern given the absence of any requirement in IGCSEs for practical learning or for learning outside the classroom. The reversal of the requirement on schools to ensure that all schools offer science-related diplomas will also serve to remove an important means by which practical activities and learning outside the classroom can be promoted for many pupils given the ways in which these qualifications are designed and structured.

Academies and free schools

14. The Committee will also be aware of the intention of the Coalition Government to expand significantly the number of academies within the state-funded education system in both the primary and secondary sectors and to promote the introduction of free schools. Notwithstanding the extent to which the revised National Curriculum will include provision for practical learning and for learning outside the classroom, it is important that the Committee notes that academies and free schools will not be under any requirement to ensure that their curricular offer is in line with the requirements of the National Curriculum.

15. Instead, academies and free schools are subject to an ill-defined and difficult-to-enforce requirement set out in their funding agreement with the Secretary of State for Education to provide a 'broad and balanced' curriculum. Given the lack of any meaningful description of the basis upon which this curricular requirement is to be established in practice, it is therefore possible that pupils attending such schools will not be offered the range of activities in this respect that might continue to be provided for within the terms of the revised National Curriculum. Any failure in these schools in respect of provision of opportunities for learning outside the classroom or practical education in science must therefore be regarded as a direct responsibility of the Secretary of State.

16. In relation to academies and free schools, it should also be recognised that currently under the terms of the Education Act 1996, schools are not permitted to charge for activities, including learning outside the classroom and practical activities that form part of pupils' curricular entitlements. However, if academies

and free schools are able to define their own curricular offers in relatively narrow terms that exclude explicit provision for learning outside the classroom or for some science-related practical activities, it is possible to envisage circumstances where schools could claim that as these activities, where offered, are outside the core curriculum, they are liable for charging. For economically disadvantaged families, this could represent a serious barrier to access learning outside the classroom or practical science-related activities in certain schools. It also raises the prospect of increased social segregation between pupils as some would be able to access school-based activities regarded as optional extras, while others would not. The Committee will therefore want to consider seriously investigating this potential consequence of the academies and free-schools programme, and the NASUWT would welcome the opportunity to share its particular concerns in this regard with the Committee in more detail.

Reductions in public expenditure on education

17. It should be recognised that learning outside the classroom and practical science-related learning represent relatively high-cost elements of educational provision for schools, given the resources, materials and additional expenditure that can be involved. In this context, expenditure plans set out by the Chancellor of the Exchequer in the Coalition Government's Comprehensive Spending Review (CSR) risk undermining the ability of schools and local authorities to ensure that pupils' curricular entitlements in this regard can be met effectively. While the Government has asserted that during the course of the CSR period, expenditure on schools will increase in real terms, it is clear that per-pupil spending overall will decline as a result of increases in pupil numbers during the period.[1] There are also legitimate concerns about the extent to which the Government's proposals for its Pupil Premium will lead to real-terms reductions in funding for a significant number of schools.[2] These concerns are further compounded by significant reductions in local authority expenditure for which schools will face

[1] HM Treasury (2010), *Spending Review 2010,* The Stationery Office, London.
[2] Chowdry, H; Greaves, S; and Sibieta, L (2010), *The Pupil Premium: assessing the options*, The Institute of Fiscal Studies, London.

pressures to compensate through diverting their own resources to replace diminished local authority provision of key education-related services.

18. As a result of these decisions, there is emerging evidence that schools are facing pressures to reduce learning outside the classroom opportunities or, where possible, reduce expenditure on practical learning provision as a direct consequence of increasing cost pressures and declining overall budgets. In addition, the NASUWT is aware of reports that constraints on funding are leading to increased demands for financial contributions from parents to support activities of this nature. The NASUWT is clear that the potential effect of these changes to levels of funding available to schools on learning outside the classroom and practical learning opportunities in science have not been taken into sufficient consideration by the Coalition Government in developing and implementing its policies in this area. The NASUWT therefore recommends strongly that the Committee seeks to undertake its own assessment in this regard and the NASUWT would welcome the opportunity to work with the Committee in progressing its activities in this area.

Health, safety and science education in schools

19. It is well established that activities related to learning outside the classroom and practical activities in schools are associated with risk to the health and safety of staff and pupils. For staff, failures in relation to the health and safety of pupils and other colleagues can have significant legal consequences and place their future careers in jeopardy. In the NASUWT's view, it is therefore critical that these risks are identified, assessed and managed effectively. Approaches based on denying that such risks exist or that downplay their nature and extent are unacceptable.

20. In its evidence to the former Children, Schools and Families House of Commons Select Committee's inquiry into learning outside the classroom undertaken in 2010, the NASUWT set out its concerns about the impact of an increasingly litigious environment on the ability of schools to organise learning outside the classroom, especially where schools believe that they may be vulnerable to compensation claims. Teachers have been vulnerable as a result of delays in the

conduct of investigations where problems have arisen or where they have individually been cited in legal action that has been instigated by parents or carers. In some instances, employers have been unwilling to provide proper representation or support for teachers, further exacerbating teachers' professional and personal liability concerns. The Union's casework continues to confirm that employers will often decline to support individual teachers on grounds of perceived 'conflict of interest' between the employee and the pupil.

21. Therefore, it is essential that processes and procedures put in place in respect of health and safety allow these issues to be addressed effectively and thereby ensure the health and safety of all those participating in such activities. The NASUWT would reject firmly any proposals to amend these arrangements in a way that would hinder their ability to ensure that all staff and pupils can benefit from effective risk management procedures. Some of the distorted and inaccurate narrative in this respect that has developed as result of the Review of health and safety undertaken by Lord Young of Graffam, *Common Sense, Common Safety,* can only be regarded as highly unhelpful.

22. With regard to the contention referred to by the Committee that these arrangements deter schools from offering learning outside the classroom experiences or practical, science-related activities, the Union's experience is that such claims are entirely without validity. Work undertaken by the NASUWT to survey its members' views of causes of bureaucracy and excessive workload in schools fail to identify health and safety responsibilities related to learning outside the classroom or practical activities as significant.

23. In addition, recent developments in these areas have worked to simplify health safety arrangements and enhance manageability at school level. For example, the Learning Outside the Classroom Manifesto, taken forward by the previous administration in close collaboration with the NASUWT, led to the establishment of a Quality Badge Scheme which accredited providers as effective in the management of health and safety and benchmarked effective practice in this area. The Union is clear that the extension of this scheme has increased confidence within the school system in relation to the incorporation of learning

outside the classroom experiences into school science curricular. It must therefore be regarded as a matter of serious concern that the sustainability of these schemes has been placed at serious risk by the cuts in education-related public expenditure being taken forward by the Coalition Government.

24. The NASUWT therefore recommends that the Committee should review the positive impact of the Manifesto and the Quality Badge Scheme on practice in schools and should ensure that its work in this area takes into full account the outcomes of this review.

Ms Chris Keates
General Secretary
NASUWT

13 May 2011

Written evidence submitted by The UK Association for Science and Discovery Centres (Sch Sci 41)

Inspiration through hands-on science at the UK's Science and Discovery Centres

Hands-on experimentation and field trips are vital to the future of science, technology and innovation in the UK. There is no substitute to capture the imagination and the excitement of discovery and learning.

Every week, 385,000 people of all ages and backgrounds engage with science at one of our member science and discovery centres or science museums. This equates to 20 million people every year, taking the time to explore and delve into science in a hands-on, experimental intriguing and personal way. Most of the 20 million are school age students, or parents of school-age students.

One of the key goals of the UK science and discovery centres is to offer school children, families and adults unusual and exciting opportunities to explore, discover, question, test and experiment on the world around them. The aim is not simply to fill people with facts, but to take them on a journey to spark their curiosity; to encourage them to continue asking questions about the world long after they leave our centres. For this reason we believe science field trips and hands-on experimentation is of vital importance

The subject might range from biomedicine to nanoscience, light to neuroscience or climate science to astrophysics. For all, the goal is to achieve a sense of wonder and excitement through hands-on interactive experiences and activities. Visitors are always encouraged to have a go, experiment and to try things out for themselves.

The vast majority of the UK's science and discovery centres are independent charitable enterprises. Their goal is to inspire and involve children and adults with the broadest range of the sciences, as well as instilling a deeper understanding of the process of science and the nature of scientific evidence. Many science centre work with local science-based entrepreneurs and innovators as well as science experts from universities, start-ups and major industries to help the public and school students explore the latest science and the issues surrounding new advances. They also offer a host of opportunities for the public to talk directly to scientists and for school students to meet inspirational science role models and inventors.

A casual observer might be forgiven for thinking that science and discovery centres are only hands-on science exhibitions. But this is just the tip of the iceberg. Taking a single example, last year one of our 60 science centres (based in Birmingham) attracted around 260,000 people, of whom 78,000 were school students and teachers who took part in targeted curriculum-linked science workshops and activities. The remaining 182,000 were family and leisure visitors. Of these, 70,000 participated in science events such as lab-based workshops, family science shows, sleepovers, story-telling, object handling sessions, molecular biology workshops, meet the scientist events and events based in community venues. Over 62,000 people also visited their planetarium to sit back and enjoy the stars.

Together, the UK science and discovery centres make up the largest publically accessible network dedicated to both hands-on science learning and family science learning. They employ an army of over 5000 professional science engagement specialists with backgrounds as wide-ranging as performance artists, scientists, ecologists, teachers, designers and film-makers. All skills which are needed to bring science alive with people from all parts of society.

Tens of thousands of teachers nationally feel visiting a centre so inspires their students that it is worth the effort of taking students on trips to centres. And of course, millions of families and leisure visitors feel the experience is sufficiently enjoyable to spend their valuable free time and money visiting.

Across the world the UK is seen as a benchmark of excellence in both creating and running science centres. The UK Government is one of the few countries in Europe that does not give any central subsidy to its science and discovery centres despite the fact that UK centres are viewed internationally as inspirational, innovative and lean organisations. All the while, delegations arrive at The Association for Science and Discovery Centres (ASDC) and UK science centres, sent from the Governments of China, India and other Asian nations. They are keen to learn from our science centres as they rapidly set up their own hands-on science centres across their nations. It is clear they see new science centres as a vital ingredient in inspiring young enquiring minds to choose a career in science, and that they see science centres vital to both their scientific and economic future.

The UK Association for Science and Discovery Centres (ASDC) is itself a charitable organisation, with 60 members from both rural and urban areas right across England, Ireland, Scotland and Wales areas. Our membership includes science centres, environment centres, national science museums, discovery centres and university departments. **Our mission is to bring together our membership to play a strategic role in the nation's engagement with science.** In addition to our not-for-profit members, ASDC has corporate members. From this year we are also inviting innovative science based organisations as key supporters of the work we and our members do.

On a final note… As a nation, and as a global society we have some huge challenges ahead. We need our young people to be confident to experiment, to explore and to try to change the future. We need our adults and aging population to better understand the sciences and to lobby for the policy changes needed for a low carbon future. We need to nurture the brightest young minds and bring back the adventure and delight of exploring and discovering the world around us. As the only UK network of year-round publically accessible science venues, the UK's charitable science and discovery centres have both the infrastructure and the passion to strive towards this.

Dr Penny Fidler
Chief Executive
The UK Association for Science and Discovery Centres

13 May 2011

Quote from David Willetts on visiting INTECH Science Centre & Planetarium

Minister for Universities and Science David Willetts said:

“Science is fundamental to our society - we need it for everything from finding cures for diseases to discovering what lies beyond our solar system. That’s why it’s so important to have excellent centres that engage people with science from a young age.

“As Science Minister it’s really encouraging to see a facility that is not only boosting the local economy but also helping to foster a future generation of scientists.”

Written evidence submitted by the Health and Safety Executive (HSE) (Sch Sci 42)

Introduction

1 HSE supports completely the importance of school science, and of the educational and personal development benefits that science field trips provide for pupils. HSE further recognises and supports the economic necessity of properly preparing Great Britain's future workforce, and the role that science and technology (S&T) should play in GB's future. HSE itself employs a considerable number of scientists and technologists, and our policy positions are underpinned by an S&T evidence base.

2 Unfortunately, some schools and teachers have seen health and safety law as a barrier that discourages them from organising practical science activities and providing pupils with the opportunity to take part; or that health and safety law requires them to apply overly bureaucratic controls that prevent teachers running dynamic science lessons. We believe this perception results from a basic misunderstanding of the expectations placed upon schools and teachers under the Health and Safety at Work etc Act 1974, coupled with related concerns about insurance requirements and fears of teachers being sued if a child is injured. HSE's interest is in criminal action (prosecutions). HSE does not investigate or take action in relation to civil claims. This submission therefore tackles the issue and impact of criminal liability and not civil liability.

3 HSE believes there is no reason why health and safety should stop schools carrying out science experiments or field trips. On the contrary, we see the proper integration of health and safety considerations into the overall delivery of the curriculum as being both natural and good teaching practice. It helps children appreciate hazards and risks, and learn how to manage them - all that is required in most cases are a few sensible precautions. Active and experiential learning is widely recognised as one of the best ways for people to learn so it is important that it is not curtailed unnecessarily. HSE has worked with educational science bodies over many years to establish and publicise what those precautions should be and to ensure they are sensible, practical and proportionate. HSE continues to work closely with those organisations.

Health and safety legislation

4 The Health and Safety at Work etc Act 1974 (HSWA) aims to secure the health, safety and welfare of people at work and the protection of people other than those at work from risks arising to their health and safety out of work activities. HSWA applies throughout England, Scotland and Wales. While responsibility for education is devolved, enforcement of HSWA is a reserved matter. Enforcement bodies drawing on HSWA may work across borders, as do many schools and organisations that run school field trips.

5 HSWA places duties on those who are best placed to control risks. It is simply constructed, with duties on:

- employers in respect of the health, safety and welfare of their employees (HSWA s2) and in respect of the health and safety of other persons who are not their employees but who could be affected by the work activity e.g. pupils (HSWA s3);
- on the self-employed for their own health and safety and the health and safety of other persons who may be affected by the conduct of the self-employed person's undertaking (HSWA s3);
- on persons in control of premises (HSWA s4);
- on manufacturers, suppliers etc of articles and substances for use at work (HSWA s6); and
- on employees in respect of their own health and safety and the health and safety of others their conduct at work could affect (HSWA s7).

6 The most relevant element of HSWA to the health and safety of pupils is Section 3. This places general duties on employers and self-employed to persons other than their employees. Section 3(1) states`*it shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety'*. The primary responsibility for pupil safety under this section sits with the employer of the staff in the school (see para 15).

7 HSWA also recognises that a failure to control risks may be due to the actions or omissions of another individual. For example, individual employees have duties under HSWA s7 to take reasonable care while at work for their health and safety, the health and safety of others who could be affected by their acts or omissions and, as regards any duty or requirement imposed on

their employer or any other person, to co-operate with their employer/the other person so far as is necessary to enable the duty or requirement to be performed or complied with.

8 HSWA is supplemented by specific regulations designed to target risks in a sector e.g. construction, or across several sectors e.g. radiation.

9 Additionally, the Management of Health and Safety at Work Regulations 1999 make the general requirements of HSWA more explicit. For example, the Regulations require employers to make a suitable and sufficient assessment of the risks to the health and safety of their employees and other persons affected by the conduct of the undertaking (this includes pupils in schools). Having done a risk assessment the employer should identify the steps needed to comply with health and safety law.

10 The Control of Substances Hazardous to Health Regulations 2002 deal with the use of substances hazardous to health, which could include substances used in a science laboratory. For example, these Regulations require employers to ensure that the exposure of their employees to substances hazardous to health is either prevented or, where this is not reasonably practicable, adequately controlled (regulation 7). Employers are, so far as is reasonably practicable, under a like duty in respect of any other person, whether at work or not, who may be affected by the work carried out by the employer (regulation 3(1)).

11 The legislation is generally goal setting – leaving the employer to determine how best to manage the risks that are created. In schools, guidance setting out good practice is provided by HSE, Local Authorities and other sector organisations. This advice on compliance provides an important steer on sensible solutions. The aim is that the organisation will determine proportionate and sensible ways to control the risks that deal with its own needs and circumstances. In this way the legislation does not stifle innovation or impose burdensome controls. It leaves the organisation choices about how to manage their own risks.

Health and Safety legislation in schools - responsibilities

12 Health and safety legislation applies to all sectors and phases of the education system, whether schools are state controlled or part of the independent sector. It is relevant to all the school activities and impacts on staff, pupils and visitors.

13 The employer of the staff at the school has the primary responsibility in ensuring the health and safety of employees and pupils who may be affected by the school activities. The employer varies with the type of school – and can be a Local Authority, a Board of Governors or a Proprietor. While this overall responsibility lies with the employer, head teachers and the school management team have considerable influence in the day-to-day running of schools. The local managers take on an important leadership role for management of all the issues within the school including the management of risks. Taken together these arrangements set out a framework that teachers work within when teaching lessons and leading field trips.

14 In the vast majority of case the headteacher in an individual school is not the employer of the staff, but as the senior local manager will have wide-ranging responsibilities. A school leader's responsibilities for health and safety in the broadest sense of the phrase exceed those requirements set out in HSWA. For example in England the National Standards for Head teachers, the OFSTED inspection framework, and requirements for safeguarding and protection of children all include minimum standards for a range of health and safety or risk management issues.

15 Under Civil Law schools and their leaders also owe a duty of care to their pupils. The law of negligence is based on a significant body of case law that has developed over many years. Schools are expected to take all reasonable care – and in effect act in a way that a reasonable parent would act. Civil Law is often cited as one the primary barriers to a range of opportunities for children as teachers and schools fear civil action. HSE does not investigate civil claims.

16 Most schools have good health and safety management arrangements in place which complement the wider actions in schools to promote the well-being of pupils and staff. The approach to managing risks in schools are well established and reflect sound management practices common across many other public and private sector organisations. HSE expects schools to have:

- clear objectives, policies and procedures integrated into the school's wider management systems;
- clearly understood responsibilities – for Local Authorities, head teachers, teachers, Governors and other staff;
- access to competent advice to ensure the focus is on real risks, and to avoid applying bureaucratic approaches to risk management;

- arrangements for involving the workforce in health and safety.

What impact does health and safety legislation have on field trips?

17 Good health and safety arrangements will help schools to provide children with a range of valuable learning experiences. It is important that schools aim to manage risk responsibly and sensibly – not trying to eliminate it altogether. Sensible health and safety means that children are exposed to well managed risks, which helps them learn important life skills, including how to manage risks for themselves. Sometimes things may go wrong – particularly where children are involved in more complex S&T experiments or field trips as part of more advanced courses eg in the sixth form. HSE has only ever expected schools and teachers to adopt sensible, obvious and widely understood precautions, such as wearing protective eyewear when conducting chemical experiments.

18 Teachers need to make judgements about how their science lessons are delivered – including making choices between pupils taking part in practical experiments or whether demonstrations by the teacher are more appropriate. These professional judgements do not need to be made in isolation by individual teachers – they can form part of the school or department's policy. However, such approaches do need to adapt to circumstances. A group of pupils with a history of discipline issues may not be the ideal candidates for higher risk experiments where discipline is important. Alternatively, demonstrating low risk experiments to the same group may not be appropriate when a hands-on experiment would better engage their interest. Such judgements are taken on a day-by-day basis by teachers on many issues and this sensible decision-making should also be applied to risk management. For example, HSE is more concerned with situations where judgments are not applied or applied recklessly – not when a decision simply proved to be a mistake.

19 Within some Local Authorities and/or schools there is a tendency for managers, school leaders or teachers to implement bureaucratic procedures. The employer may impose some of these systems on schools. In other cases, schools may slavishly follow a model risk assessment, giving no thought to whether that assessment applies to the local circumstances. Sometimes this leads to risks not being managed – but in many cases these approaches will lead to schools going beyond what is sensible to manage relatively low risk situations.

20 A small number of schools and teachers do not treat health and safety in a proportionate manner. Essential health and safety controls may be disregarded or dismissed as bureaucracy – a typical symptom of this in science laboratories is the retention of out-of-date or banned substances or poor storage of flammables. Accidents during science in schools are rare, but typically occur when there is no consideration of the real risk and a diversion from long established safe practice followed by most other schools. These are issues that can be managed by strong school and departmental leadership that encourages and supports innovation and tackles bad practice in equal measure.

What impact does health and safety legislation have on field trips?

21 Organising and running any school trip can put a lot of pressure on teachers. Sometimes there are genuine concerns about requirements and responsibilities – but most trips simply involve everyday risks. There are some unfortunate myths about individual teachers being held liable and personally sued. HSE can only comment on perceptions about criminal prosecutions as HSE does not investigate or take action on claims about civil liability. In the very small number of cases where teachers have been individually prosecuted, it has happened because they have ignored direct instructions and departed from common sense – by taking actions that a rational person would not take. HSE wants to encourage those organising trips to simplify the planning and authorisation arrangements for trips that involve everyday risks – and focus their attention on how best to manage the risks on those few school trips that have significant challenges, but which also provide pupils with the extremely valuable learning and developmental benefit.

22 Many thousands of activities take place every year in schools and other youth organisations. Young people take part in foreign exchange visits, adventure activities, work placements and a wide range of curriculum based field activities. Most of these events take place without incident, the learning is immense and the young people are left with memories of an enjoyable experience, which means that both the enjoyment and the learning will stay with them for a long time. The problem we face is that isolated incidents get a huge amount of media coverage. The reality is that they are rare events. There is little or no coverage of the many events which take place without incident and the enormous benefit which young people derive from them.

Guidance on school science and field trips

23 HSE has worked closely with S&T stakeholders for many years. These important sector organisations have provided guidance, risk assessments, case studies and advice to schools that aim to encourage sensible management of risks in school science. Two of the key organisations with an interest in school science are CLEAPSS (Consortium of Local Education Authorities for the Provision of Science Services) and the Scottish Schools Equipment Research Centre (SSERC).

24 CLEAPSS provides support for member Local Authorities in England and Wales. CLEAPSS works in the field of school and college science, from foundation stage through to A Level or equivalent. CLEAPSS provides general support for practical work with information, advice and training about laboratory design and practice, technicians and their jobs, equipment, materials, living organisms and especially health and safety. This guidance is well recognised by practitioners in schools. Some support for technology, art and design is also provided. Guidance includes model risk assessments, a laboratory handbook, specific publications, guides and leaflets. In addition courses and workshops are run for teachers and technicians

25 One example where HSE worked with CLEAPSS was in the development of practical guidance for the use of ionising radiation in schools. Practical experiments greatly enhance the process of teaching the properties of radiation in schools and are important in aiding students' understanding of the subject. HSE had input into the development of a good practice guide published by CLEAPSS in 2008 that aimed to support practical work whilst enabling schools to apply sensible and proportionate precautions.

26 A sister organisation SSERC performs a similar function in Scotland. SSERC is a registered educational charity which covers science, technology and safety in schools in Scotland. It is funded by its member organisations (including the 32 Scottish Local Authorities) and is part funded by the Scottish Government. It provides a service for Local Authorities, teachers, student teachers and technicians in Scotland and has a recognised lead role in science education, providing Continuing Professional Development (CPD) for managers, teachers and technicians. SSERC promotes and supports safe and exciting learning and teaching in science and technology.

27 The Association for Science Education (ASE) is a UK wide charity promoting high quality science education. The ASE is the largest subject association in the UK. Members include teachers, technicians and others

involved in science education. ASE plays a significant role in promoting excellence in teaching and learning of science in schools and colleges. Working closely with the science professional bodies, industry and business, the ASE provides a UK-wide network bringing together individuals and organisations to share ideas and tackle challenges in science teaching, develop resources and foster high quality Continuing Professional Development.

28 The Education Departments across Great Britain produce guidance for Local Authorities and schools on a range of health and safety issues:

- In England, the guidance produced to assist the planning of school trips is under review. This means that guidance for schools will be made leaner so as to enable a clearer distinction between what the law requires and what is simply good practice.

- In Wales, the Welsh Government hosts the 'Education Visits Guidance' which was devised and periodically reviewed by Local Authority Outdoor Education Advisors. Whilst minimising needless bureaucracy was always a governing principle of the Educational Visits guidance, in conjunction with offering the risk-benefit approach to learning, a review by Outdoor Education Advisors is currently being undertaken.

- In Scotland, guidance is contained in the Scottish Government's "Health and Safety in Educational Excursions - A Good Practice Guide" published in 2004. A recent review of this guidance concluded that it was still fit for purpose. In addition, the Learning and Teaching Scotland website has web based resource material for teachers covering a variety of outdoor learning scenarios including field trips.

What do the statistics tell us about health and safety in schools?

29 Slips, trips and falls remain the most common cause of major injuries in every workplace. They account for around 40% of all injuries reported in schools. A total of 50 058 injuries[1] in primary and secondary schools were reported to HSE for the five year period 2005/06 to 2009/10. Approximately 30% of these involved employees; the remaining 70% involved non employees, which includes pupils.

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[1] RIDDOR data needs to be interpreted with care because it is known that non-fatal injuries are substantially under-reported. Currently, it is estimated that just over half of all such injuries to employees are actually reported.

30 Risk from practical science lessons and field trips can be put into context through analysis of accident reporting statistics – particularly taking into account the millions of children[2] taught science each year. In the five-year period 2005/06 to 2009/10 in the primary and secondary education sectors 478 injuries to employees and members of the public (i.e. pupils) were reported as occurring during science lessons. A full breakdown of the statistics and explanatory notes are provided at Appendix 1.

31 Over the same five year period HSE has taken 29 prosecutions in the education sector – 18 in the primary, secondary and vocational sectors. Of these, 16 have concluded with a conviction. One of the remaining two cases is unfinished, the other under appeal.

32 None of these 18 prosecutions related to school science. Two related to school trips, but these were not field trips, and three related to classroom activities, but these were not science rooms or science lessons. Nevertheless, despite the small number of prosecutions that are unrelated to science there may be a ripple effect that influences the perceptions amongst schools and science teachers.

Tackling the perceptions of bureaucracy

33 HSE has promoted a very clear policy on sensible risk management. Since 2006, HSE has sought to make clear the importance of organisations recognising the balance between benefits and risk and focusing on real risks rather than trivia. In 2007 HSE established the Sign up to Sensible Risk Campaign to combat the growing number of myths that are undermining important health and safety legislation. Local Authorities were invited to publicly sign up to the campaign to encourage them to be sensible and proportionate in their decision-making, their advice giving and their own enforcement. This aimed to have an impact on guidance Local Authorities gave to schools within their control.

34 HSE believes that risk management should be about practical steps to protect people from real harm. The aim is to achieve a balance between the unachievable aim of absolute safety and the kind of poor management or risk that damages lives and the economy. HSE has produced model risk assessments to ensure that organisations understand what sensible assessment involves.

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2 DfE 2010 School Census - In January 2010 there were around 8.1 million pupils (headcount) in all schools in England

35 Between 2007 and 2010 HSE used a series of cartoons called Myth of the Month to challenge the urban myths so prevalent in the media and wider society relating to health and safety. These misleading stories and myths can distract people from the serious business of managing real health and safety risks. The cartoons highlighted ridiculous 'elf and safety' stories that have featured in media reports, and gave details of the real purposes of health and safety management. These cartoons tackled a wide range of issues from the misuse of risk assessment to the banning of events or use of everyday equipment like stepladders.

36 Monthly cartoons were targeted at the many myths across education including:

- Egg boxes banned from craft lessons as they might cause salmonella – August 2007
- If a pupil is hurt the teacher is likely to be sued – February 2008
- Health and safety rules stop classroom experiments – November 2009

37 In 2009 HSE launched its new strategy – "*The Health and Safety of Great Britain - Be part of the solution".* While the overriding mission of the Strategy was to prevent death, injury and ill health to those at work and those affected by work activities, it recognised particular issues that needed to be addressed:

- The increased risk aversion in society as a whole;
- Health and safety increasingly being used as a convenient excuse for not doing a whole host of activities.

38 The strategy includes a set of common goals including leadership, competence and management of major hazards. Also included is the goal to focus on the core aims of health and safety and by doing so help distinguish between real health and safety and trivial or ill-informed criticism.

Demonstrating leadership on sensible health and safety

39 HSE's efforts to tackle over zealous approaches to health and safety, particularly in education, have been led by HSE's Chair, Judith Hackitt. The Chair has attended conferences, challenged stories in the media to put the record straight, supported key organisations and individuals in their promotion of school science, and proactively sought to encourage schools bringing science to life through practical experiments and field study. HSE believes all

these actions are important to help encourage schools to inspire and motivate the next generation of scientists and engineers, and widen children's understanding of risk.

40 For example, in January 2009 the HSE Chair worked with the Chief Executive of the Institution of Chemical Engineers to encourage teachers to re-introduce exciting and engaging practical classroom demonstrations. This was designed to promote the IChemE's "Top 10 Flash Bang Demos". These demonstrations encourage teachers to add greater practical focus to their lessons. The chair took part in a visually exciting science experiment to enhance the message.

Current priorities for HSE - *Common Sense Common Safety*

41 In 2010 the Government published *Common Sense Common Safety* – a report of a review of the operation of health and safety laws commissioned by the Prime Minister. It makes recommendations for reducing unnecessary bureaucracy and for the proportionate application of health and safety law and identifies proposals for tackling the compensation culture. HSE is working with stakeholders to respond to the recommendations in the report in a number of key areas – including education.

42 One specific recommendation is to simplify the guidance and procedure for risk assessment in classrooms. HSE has been working with stakeholders to produce tools to help teachers understand the risks within their classrooms – helping reduce the burden on teachers by enabling them to focus on the real risks and not divert them from their important teaching role. A risk assessment tool was trialled between November 2010 and February 2011 and, following feedback from stakeholders, will be re-launched as a simple checklist for traditional classrooms.

43 *Common Sense Common Safety* also placed recommendations on other organisations. HSE has established an Education Working Group to oversee the development of responses to the education related recommendations in *Common Sense Common Safety*. The Working Group includes input from the Education Departments across Great Britain and other stakeholders.

44 The responses to the education recommendations in *Common Sense Common Safety* across the three nations are likely to be progressed in slightly different ways. For example, in England the Department for Education (DfE) is developing a Single Consent Form to simplify the process for taking children on educational visits. DfE will support this with guidance for schools

that aims to reduce the perceived bureaucracy associated with organising school trips.

45 In Scotland, the *Common Sense Common Safety* recommendations are in line with much of the work that is already in hand to reduce barriers to young people accessing learning opportunities that are beneficial to them. An Outdoor Learning Safety Management working group has been appointed to report to Scottish Ministers in spring 2011. This group is addressing many of the issues covered in the report. The proposal is for a single skeletal policy on outdoor learning safety that would be used nationally by Scottish Local Authorities. The aim is to have a simplified approach to outdoor learning which will reduce bureaucracy and variation between Local Authorities. As part of this approach, the use of consent forms will be considered.

46 Similarly, in Wales, barriers to enhance and develop learning through realistic health and safety, has been the mainstay principle of the Welsh Assembly Government in its interaction and communication with Schools. The recommendations in *Common Sense Common Safety* were accepted by the Minister for Education and Skills, recognising the simplification of systems, and the removal of needless bureaucracy. Work is currently ongoing in Wales, including participation in the HSE led educational working group to ensure a common theme is maintained.

47 While it is not a recommendation in *Common Sense Common Safety*, HSE has offered to clarify how health and safety law applies to school trips in a High Level Statement to provide schools, Local Authorities and teachers with clear messages about sensible risk management on school trips. This will apply equally to science field trips. HSE wishes to encourage all schools and Local Authorities to remove wasteful bureaucracy imposed on those involved in visits and activities – so that the focus is on the real risks[3] and not on paperwork. The high level statement will make clear that HSE's primary interest is real risks arising from serious breaches of the law and that any HSE investigations are targeted at these issues. The statement will outline the considerations HSE takes into account in reaching decisions about prosecution following an accident, and make clear that such action is very rare. The Statement will provide a further opportunity to actively promote the existing policy lines relevant to school science field trips.

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[3] The Courts have made clear that when health and safety law refers to risks, it is not contemplating risks that are trivial or fanciful. It is not its purpose to impose burdens on employers that are wholly unreasonable (R v Chargot (2009) 2 All ER 660 [27])

Appendix 1

Reported injuries to employees and members of the public (1) in primary and secondary education (2) occurring during science lessons (3) 2005/06 - 2009/10p (4)

	2005/06	2006/07	2007/08	2008/09	2009/10
Major injury - employee	4	3	4	1	1
Over-3-day injury - employee	0	3	11	6	10
Non-fatal injury - member of public	58	62	66	99	150
Total - reported injuries	62	68	81	106	161

Notes

(1) Injuries are reported and defined under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR).
(2) Standard Industrial Classification of Economic Activities (SIC) codes 80100 'Primary education', 80210 'General secondary education' and 80220 'Technical and vocational secondary education'. The SIC system is used in UK official statistics for classifying businesses by the type of activity they are engaged in. The latest version is SIC2003.
(3) A search was conducted of the 'ICC notifier comments' field in order to capture details of such incidents. The following terms were used: 'science', 'physics', 'chemistry', 'biology', 'geography', 'laboratory'. Any interrogation of the comments provided by notifiers is by its nature an error-prone process. This is because RIDDOR notifiers have freedom to express the details they supply in the way that they feel is most appropriate. As a consequence of the flexibility allowed during notification, it is very difficult to group together specific incidents from the individual reports that are submitted, hence there is no easy way of ensuring that all records are accounted for.
(4) The annual basis is the planning year from 1 April to 31 March. Statistics for 2009/10 are provisional, denoted by 'p'.

General caveats on RIDDOR data
RIDDOR data need to be interpreted with care because it is known that non-fatal injuries are substantially under-reported. Currently, it is estimated that just over half of all such injuries to employees are actually reported.

Health and Safety Executive

6 June 2011

Written evidence submitted by the Association of British Insurers (ABI) (Sch Sci 43)

1 Response from the Association of British Insurers

1.1 The ABI is the voice of insurance, representing the general insurance, investment and long-term savings industry. It was formed in 1985 to represent the whole of the industry and today has over 300 members, accounting for some 90% of premiums in the UK.

2 Executive Summary

2.1 This paper discusses the ways in which insurance, and the risk assessment and management techniques which underpin insurance, enables schools to undertake a varied programme of activities outside the classroom, enhancing our children's education. It covers insurance practice in dealing with both the maintained and independent sectors.

2.2 Insurance provides both the means to fund legitimate claims for compensation following accidents or injury in schools or during educational activities and advice and expertise in minimising the likelihood and impact of such events.

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2.3 In pricing the cover to Local Authorities and schools, insurers do not generally differentiate between in school activities and those outside the classroom such as science field trips. Similarly employers are able to include students on work placements within their Employers' Liability covers. Insurance therefore enables the full range of educational opportunities.

2.4 In the maintained sector, Local Education Authorities' insurance is often provided as part of the wider Local Authority's cover (although academies will take out insurance themselves). Only around 3% of Local Authority bodily injury claims arise from educational activities (inside and outside the classroom). The cost of this insurance to a Local Authority is therefore almost entirely driven by non-educational services.

3 Introduction

3.1 The Committee has noted press reports that the number of practical experiments in science lessons in schools and science field trips may be in decline.

3.2 The Committee is carrying out an inquiry into practical experiments in science lessons and science field trips and invites written submissions from those with an interest in the subject, especially from pupils aged 11-18, their teachers and science undergraduates who have recently left school.

3.3 It is understood that the Committee may be under the impression that one of the barriers to running practicals and fieldtrips could be cost (and insurance being an obvious cost consideration).This evidence refutes any suggestions that insurance is a barrier to these activities and, on the contrary, makes the case that insurance is, in fact, an enabler for them.

4 Background

4.1 Every year, millions of pupils are involved in school sports, school field trips and outward bound activities and most students now go on some form of work placement with an employer. This activity is vital in extending pupils' experience and in undertaking practical tasks that build knowledge, test skills and add an element of fun. It can also help develop young personalities and prepare young people for the world of work.

4.2 Any activity in life involves risks and some educational activities deliberately expose pupils to risk as part of the learning process. But risk can be assessed and managed to acceptable levels and the consequences or impact of accidents reduced by taking sensible precautions. On occasion something will happen that results in the injury or, exceptionally, the death of a pupil or staff member. In these situations the legitimate claims for compensation by the injured party can be met by insurance, thus protecting the school or Education Authority's budget from unexpected liabilities.

4.3 In the event of an accident or other incident causing injury or death, school staff, pupils and visitors to the school site can be compensated either directly by the Local Education Authority or school, or via insurance cover. The same is true when staff and pupils are engaged on an activity which takes them away from the school site.

4.4 Inevitably activities outside the classroom take place in a less controlled environment where the possibility of accidental injury is greater. Some activities, such as Outward Bound trips, are considered beneficial precisely because they expose pupils to, and teach pupils to manage, risk.

<u>Insurance Cover</u>

4.5 Insurance provides financial protection to staff and pupils whether in the UK or travelling abroad. Three main types of insurance are relevant:

4.6 *Employers' Liability*—meets the costs of claims resulting from an accident at work (or an occupational disease). Normally this provides cover for paid employees only, but can be extended to include volunteers. In addition, employers covering work placements can extend cover to students on their premises.

4.7 This insurance is compulsory, although Local Authorities are exempted and may choose to self-insure.

4.8 *Public Liability*—meets the cost of claims for injury or illness, or damage to property, for those not employed by the insured. It is not a compulsory insurance except in a few very particular cases, such as riding schools.

4.9 *Personal Accident*—provides specified cover for a defined list of injuries. It can be bought by individuals or as a group cover. For example, many Local Authorities and independent schools purchase this cover for their pupils whilst they are engaged in school activities, including sports, outdoor pursuits and field trips.

4.10 In addition, Local Authorities and schools may choose to take out travel insurance (including medical cover, lost baggage, accommodation and return travel costs) particularly for foreign trips.

Risk Assessment and Management

4.11 Risk assessments have been widely adopted as good practice by Local Education Authorities and schools. Insurers can give advice on the factors that should be considered and the way to approach risk assessment. Normal insurance practice in the maintained sector relies on schools adhering to good practice guidelines.

Underwriting Practice

4.12 In the maintained sector insurance is usually provided through a comprehensive contract covering the whole of the Local Authority's activities (although academies will take out insurance themselves). Rating is determined by the mix of services the Local Authority provides and the particular claims experience of that authority. No specific information on the number or nature of science field trips is requested and education outside the classroom is not considered a material fact in assessing the risk profile of the authority or in pricing.

4.13 Zurich Municipal, the market leader in this sector, reports that just 3% of Local Authority bodily injury claims relate to educational activities. They do not record the division between on-site and external activities and therefore are not able to separately assess this.

4.15 Insurers like Ecclesiastical and RSA are also heavily involved in other educational sectors like independent schools and academies.

Claims Handling

4.16 Where an accident or injury occurs and relevant insurance is in place the insurer will often undertake the administration of the claim, including handling legal action should the claimant decide to pursue this route.

Association of British Insurers

1 June 2011

Written evidence submitted by Ofsted (Sch Sci 44)

I am pleased to forward a short written submission from colleagues at Ofsted in response to the call for evidence and questions issued as part of the above inquiry.

I also enclose a copy of our recent survey report on science education in England from 2007 to 2010, which was published at the start of this year. This report, *Successful science*, is one of Ofsted's triennial surveys on the national curriculum subjects.

Paul Harrison
Parliamentary Affairs Manager
Ofsted

27 May 2011

Ofsted response to the House of Commons Science & Technology Committee's call for evidence on practical experiments in school science lessons and science field trips

Ofsted's most recent evidence on science education is summarised in the report *Successful science: an evaluation of science education in England 2007-2010*, published in January 2011.

1. How important are practical experiments and field trips in science education?

The importance of practical work is summarised in the first key finding of the *Successful science* report:

In the schools which showed clear improvement in science subjects, key factors in promoting students' engagement, learning and progress were more practical science lessons and the development of the skills of scientific enquiry.

This importance is emphasised in the report's recommendations that:

Primary schools should ensure that pupils are engaged in scientific enquiry, including practical work, and are developing enquiry skills.

and

Secondary schools (and colleges) should ensure that they use practical work and scientific enquiry as the key stimulus to develop scientific knowledge, understanding and skills.

However, practical work needs to be well planned, with clear learning objectives if students are to benefit from it. In paragraphs 20-22 of the report, Her Majesty's Inspectors (HMI) analyse what makes effective practical work. In the schools visited where students' progress in science was no more than satisfactory, the opportunities for them to design and carry out experiments were limited; too much of the practical work was prescriptive, with students merely following instructions. In the schools where the highest standards were observed, students were involved in planning and carrying out regular science investigations, so that they understood the processes involved.

Two contrasting examples of practical work in science are provided in paragraph 35 of the report. The first illustrates how simply exposing students to practical work does not, in itself, promote learning. The second illustrates some of the best practice observed, where the teacher had very effectively prepared students to generate their own questions, form hypotheses and plan and carry out their own practical work. This example also demonstrates how ICT can be used to enhance the analysis of data generated by experimental work.

One section of the *Successful science* report focuses specifically on features of outstanding teaching and learning, and the case studies in paragraphs 93 and 95 deal particularly with practical, experimental work. Another section of the report indicates how satisfactory lessons can be improved, to make them good; case studies relating specifically to practical work are provided in paragraphs 101, 103, 104, 105 and 107.

Many schools organise one-day science-related trips to science exploratories, museums and zoos etc. However, few organise field trips that might involve exploration of the natural environment; school grounds tend to be used for this area of learning. Few schools organise science-related field trips that involve overnight stays.

Inspectors report that enrichment and extra-curricular activities generally had a positive impact on primary pupils' attitudes to science (paragraph 49). The range of extra-curricular activities seen in secondary schools was broader than that in primary schools, but activities did not usually engage large numbers of students (paragraph 56).

2. Are practical experiments in science lessons and science field trips in decline?

There is no evidence from inspectors' visits to schools that there is a decline in practical work carried out in science lessons. In referring to the key issues from the previous triennial science report (published in 2008), the *Successful science* report comments that scientific enquiry continues to be at the heart of the most successful science education. It also notes that practical work has had a high profile in the last few years, and that its importance has been widely recognised.

Ofsted has no evidence to indicate that there has been a decline in science field trips.

3. What part do health and safety concerns play in preventing pupils from performing practical experiments in science lessons and going on field trips?

The evidence from specialist science visits is that schools give good consideration to health and safety issues. Guidance for schools generally places sensible restrictions on what they can and cannot do in science.

There may be individual schools where health and safety considerations have affected practical science work and field trips. However, there is no evidence from the visits to schools carried out by HMI that this is a widespread or serious problem.

4. Do examination boards adequately recognise practical experiments and trips?

This question could be interpreted in a number of ways. In paragraph 20 of the *Successful science* report, inspectors note that schools in which practical work was too prescriptive were often influenced too much by the specific ways in which practical work and scientific enquiry skills were assessed for GCSE and, as a result, were less concerned with providing opportunities for wider-ranging investigations.

Ofsted

27 May 2011

Successful science

An evaluation of science education in England 2007–2010

The report evaluates the strengths and weaknesses of science in primary and secondary schools and colleges inspected between June 2007 and March 2010. There has been an improving trend in the provision of science education over the period of the report, especially in secondary schools, but there are areas that need further improvement, especially in primary schools. In schools that showed clear improvement in science subjects, more practical science lessons and the development of the skills of scientific enquiry were key factors in promoting pupils' engagement, learning and progress. This report identifies outstanding teaching and describes how to move from satisfactory to good or outstanding practice.

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No. 100034

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Executive summary

This report draws on the results of visits by inspectors to 94 primary, 94 secondary schools and two special schools between June 2007 and March 2010. These schools were selected broadly to represent the profile of schools in England, but excluded schools in Ofsted's categories of concern. It also draws on the outcomes of subject conferences organised by Ofsted. During the past year, 2009–10, inspectors reported on post-16 science education in 31 colleges and their reports have also formed part of the evidence.

There has been an improving trend in the provision of science education over the period of this report, especially in secondary schools, but there are areas that need further improvement, particularly in primary schools. The most important focus for schools is to ensure that pupils are engaged and challenged by their work in science, particularly in scientific investigation and how science works. Students need access to relevant courses that provide them with clear, high-quality pathways through their education, allowing them to attain the highest standards possible, both in the short term and when they progress to further and higher education. The best schools are already doing this.

Achievement in science was either good or outstanding in just over two thirds of the schools visited. While this overall proportion of 'good or outstanding' was similar for primary and secondary schools, there was a larger proportion of secondary schools where achievement was judged to be outstanding. Overall levels of attainment in primary schools, as measured nationally by teacher assessment data, were broadly similar to those observed during the previous inspection cycle; however, attainment at the higher levels was slightly reduced. Over the same period, success rates for separate science subjects at GCSE level have increased significantly: in 2010 around 12,000 more students than in the previous year were awarded grades A* and A at GCSE in each of the three separate sciences of biology, chemistry and physics.

The highest-performing schools, both primary and secondary, had clear priorities for raising standards and had several features in common. These included rigorous monitoring and evaluation of performance, aligned with challenging target-setting for individual pupils. The schools focused strongly on improving the quality of teaching and learning, with staff within science departments planning together and sharing good practice. These characteristics are explored later in the report.

In both primary and secondary schools, teaching in science was at least good in around three quarters of the schools visited. This proportion is higher than for schools' overall performance in teaching and learning. Science, being a core subject, is a priority area for schools compared with the foundation subjects.

While the quality of teaching in the primary and secondary schools visited was similar overall, there was a slightly higher proportion of outstanding teaching in the secondary phase. Teaching was good when teachers had a clear understanding of what knowledge, understanding and skills were to be developed; understood how development in scientific enquiry promotes effective learning; understood the relationship between concepts and the cognitive demand they make; and were clear about what pupils already knew, understood and could do. The impact of good teaching was seen when pupils understood clearly the standards they had achieved; knew what they needed to do to improve and were involved in peer and self-evaluation; took part in decision-making, discussion, research and scientific enquiry; and were engaged in science that had relevance to their lives. In none of the schools visited was science teaching overall inadequate.

Primary teachers' take-up of science-specific continuing professional development was low in the schools surveyed. While much of the professional development they received overall was relevant to science, it was often generic, for example being focused on improving teaching and learning or assessment generally. In just under two thirds of the primary schools where science-specific continuing professional development was evaluated, it was no better than satisfactory. In the secondary schools where this provision was evaluated, the picture was better: nearly six out of 10 secondary schools had professional development for science that was good or outstanding.[1]

The curriculum in the best schools, both primary and secondary, engaged pupils' interest and enthusiasm and promoted good progress in knowledge, understanding and skills in science. Again, the curriculum was more often outstanding in the secondary schools visited than in the primary schools. This was achieved best through collaboration among teachers on planning for science and the effective sharing of good practice. In secondary schools, the introduction of a wider range of courses since September 2006 has been beneficial. In the last year covered by this report (2009–10), entries at GCSE for each of the three separate sciences increased by approximately 30,000. The entitlement of students achieving Level 6 in science at the end of Key Stage 3 to study the three separate sciences at GCSE has promoted recruitment to post-16 A-level science courses. Schools that entered students inappropriately for vocational courses such as BTEC limited their choice of pathways through post-16 education.

Post-16 science education has been inspected in both schools and colleges. Science provision was good or outstanding in 15 of the 31 colleges where science and mathematics were a focus for inspection and was inadequate in five. The proportion that was inadequate is a matter of concern, as is the proportion of good and outstanding provision which was lower than that earlier in secondary education. The strengths and weaknesses seen in science in these colleges were also often evident in school sixth forms. Since the last report, lessons where notes are simply dictated to students were seen less frequently. Good practices seen in Key Stage 3 and 4 have been transferred to sixth form teaching. These included more frequent assessment being used to inform planning and teaching, more rigorous target-setting and regular monitoring of progress.

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[1] This refers to the 45 of the 78 secondary schools visited where a judgement on this aspect was made.

In the schools visited in 2007–10, assessment was better overall than it was for the schools featured in the last three-yearly report. It was good or outstanding in just over three quarters of the secondary schools and slightly under two thirds of the primary schools visited. In the secondary phase, there was a greater focus on the performance of individuals, with effective monitoring and tracking systems that allowed their progress to be identified. In a welcome development, a smaller proportion of schools in this survey compared only the performance of classes and cohorts rather than individuals. The increased focus on individuals' performance and that of different groups provided a good basis for intervention with them and promoted progress more effectively.

Overall, teachers used information and communication technology (ICT) effectively in their teaching. In both primary and secondary schools, ICT was used to present pupils with experiences that could not be provided first-hand. Teachers used ICT to build ideas pictorially and diagrammatically, using data from a range of sources, including the internet. Laptops were used to capture, manipulate and display data to enhance learning and promote the development of scientific skills. The use of ICT in the outstanding schools involved pupils in interactive presentations and independent research.

The removal of the requirement for statutory tests in science at the end of Key Stages 2 and 3 has helped schools to avoid an undue concentration on revision in Years 6 and 9 and freed teachers to be innovative in planning their teaching and in enriching the science curriculum. The increased range of courses for students at Key Stage 4, including the three separate sciences and vocational science, has also provided breadth in the science curriculum to meet the needs of a wider range of students, although not all the students surveyed have benefited from this yet.

Key findings

- In the schools which showed clear improvement in science subjects, key factors in promoting students' engagement, learning and progress were more practical science lessons and the development of the skills of scientific enquiry.
- Although pupils' progress in science was good or outstanding in 70% of the primary schools visited, a lack of specialist expertise limited the challenge for some more able pupils. Progress was outstanding in one in 10 of the primary schools visited, compared to one in six of the secondary schools. This is reflected in the slight decline since 2007 in the performance of higher-attaining pupils in teacher assessments in science at the end of Key Stages 1 and 2.
- Progress of students in science was good or outstanding in around two thirds of the secondary schools visited. Some improvements in achievement were observed in lessons during the course of visits, often associated with courses that were better matched to students' needs. National standards have increased slightly in Key Stage 3 over the period of the survey. The proportion of A* to C

grades awarded at Key Stage 4 has remained approximately the same but the proportion of students achieving grades A* and A has increased.[2]

- The removal of the requirement to carry out statutory tests in science at the end of Key Stages 2 and 3 has encouraged teachers to plan engaging schemes of work in science that avoid an undue focus on revision in Years 6 and 9. It has provided scope to vary the length of key stages appropriately and provide greater enrichment.
- Standards at A level in science subjects as seen in national data have shown a steady rise over the period of this report. In the schools visited, this improvement was associated with teaching which, increasingly, engaged students more actively in their learning. This development was less evident in the colleges visited.
- Science was good or outstanding in 15 of the 31 colleges where it was inspected; it was satisfactory in 11 and inadequate in five. No other post-16 curriculum area in colleges was judged to have such a high proportion of unsatisfactory provision.
- The introduction of the new science GCSEs in September 2006 resulted in a greater number of courses being provided to meet the needs of all students. In the schools surveyed, these have been successful, in the main, in allowing more higher-attaining pupils to study three separate sciences. This has contributed to the increased recruitment of students to A-level courses in the sciences.
- The availability of vocational courses had a positive impact on the motivation and achievement of students for whom academic programmes were less suitable. However, some schools had used these courses too extensively, entering students for vocational rather than academic qualifications and, as a result, restricting students' opportunities to study A-level sciences.
- More rigorous monitoring and tracking have provided a better basis for teachers to plan with individual students in mind. This development aligns with greater challenge for many students through more effective target-setting.
- Despite some positive initiatives, such as the Primary Science Quality Mark and the Association for Science Education's publication for primary schools 'Be safe', there has been insufficient professional development in science to tackle the lack of confidence among primary teachers, particularly in their understanding of scientific enquiry skills and the physical sciences.
- Lack of specialist training, and their normally short tenure in the role, limited the effectiveness of the science coordinator in developing teaching and raising achievement in some of the primary schools visited.
- Secondary teachers in particular benefited from attending courses at the network of Science Learning Centres, but too few of the schools visited had taken advantage of this high-quality provision.

[2] See Annex B for detailed data.

Recommendations

Primary schools should:

- ensure that pupils are engaged in scientific enquiry, including practical work, and are developing enquiry skills. They should be providing a balanced programme of science education for all year groups that develops science knowledge and understanding and has a significant focus on developing skills
- make provision for effective continuing professional development to support and extend teachers' knowledge, understanding and skills in science and their confidence in teaching it
- invest in developing the role of the science coordinator to provide effective, sustained leadership in the subject and promote improvements in teaching and learning.

Secondary schools and colleges should:

- ensure they use practical work and scientific enquiry as the key stimulus to develop scientific knowledge, understanding and skills
- ensure that changes they make to the duration and nature of the Key Stage 3 curriculum are planned carefully, with a focus on good teaching and learning and to ensure coherence with science provision in Key Stage 4
- provide a range of science courses in Key Stage 4 that are suitably matched to students' needs and relevant to a life of continuing education, training or employment in a technological age
- provide good advice and guidance to students about curriculum choices in science at Key Stage 4 which have clear progression routes into good-quality post-16 education and training
- ensure that the science curriculum is engaging and relevant to students' needs and requires their active participation within and beyond the classroom; and that it promotes strong development of knowledge and understanding to be applied to science activities throughout their school or college career and into continuing education, training or employment.

Part A. Science in primary and secondary schools

Introduction

1. Science has been a core subject since the introduction of the National Curriculum, alongside English and mathematics, in 1989. It has provided a distinct area of learning and development, one that is necessary to prepare all pupils for continuing education, training and living in a technological society. This importance continues and is evidenced by the requirement for all pupils to study science from the age of five to 16. Until 2009 this importance was also signalled by the statutory tests in science at the end of Key Stage 2. In the autumn of 2008, the then Government announced the cessation, with immediate effect, of the requirement for schools to use national tests in science for 14-year-olds. Schools are still required to report on standards in science at these key points, but through teacher assessments.

2. Ofsted has reported on science education since 1993 and has identified areas that are key to success.[3] In 2008, *Success in science* covered the period from 2004 to 2007.[4] An update on some of the report's key findings is given below. Some of them are developed further in this report, building on evidence from the latest three years of science inspection visits.

Key issues from the last triennial science report, 2008

3. **Key finding:** Outcomes of tests and public examinations in science have not changed substantially over the last three years at either primary or secondary level. While being satisfactory, there is clear scope for improvement.

   Update: At the end of Key Stage 1, teacher assessment of pupils' performance showed a slight fall in the proportion of pupils attaining the higher Level 3, but otherwise performance had not changed between 2007 and 2009. At the end of Key Stage 2, teacher assessment of performance showed a small gradual increase in attainment from 2006 to 2009. However, the proportion of pupils attaining the higher Level 5 was static from 2007 to 2009. At the end of Key Stage 3, teacher assessment showed a moderate improvement in attainment from 2005 to 2007 and some continued improvement since then. At the end of Key Stage 4, attainment in GCSE has remained at about the same level since the first awards of grades for the new science GCSEs in 2008.

   In the period 2007–09, there was a slight decline in the proportion of students attaining grades A and B at AS level in each of biology, chemistry and physics. At A level during the same period, however, the proportion of students attaining grades A and B rose in each of the subjects, as did the number of entries. (Annex B provides national data.)

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[3] *Science: a review of inspection findings 1993/94*, Ofsted, 1995.
[4] *Success in science* (070195), Ofsted, 2008; www.ofsted.gov.uk/publications/070195.

4. **Key finding:** Of the schools visited, those with the highest or most rapidly improving standards ensured that scientific enquiry was at the core of their work in science. Pupils were given the opportunity to pose questions, and design and carry out investigations for themselves.

   Update: Scientific enquiry and other aspects of 'how science works' continue to be at the heart of the most successful science education.[5] 'How science works' focuses on the critical analysis of evidence and uses this to support or refute ideas and theories. Effective enquiry work involves exploring questions and finding answers through gathering and evaluating evidence. Pupils need to understand how evidence comes from the collection and critical interpretation of both primary and secondary data and how evidence may be influenced by contexts such as culture, politics or ethics. Practical work is one component of 'how science works' which has had a high profile in the last few years, and its importance has been widely recognised. Supported by the Department for Education and the Gatsby Charitable Foundation, Science Community Representing Education published a report called *Practical work in science: a report and proposal for a strategic framework* in December 2008.[6] This has given rise to 'Getting practical', a programme of professional development that is designed to support teachers, technicians and higher level teaching assistants at primary, secondary and post-16 levels.[7]

5. **Key finding:** Teaching and learning were at least satisfactory in almost all of the schools visited. However, within this generally positive picture, there were recurring weaknesses, particularly in planning and assessment.

   Update: Inspectors saw improvements in collaborative planning in both primary and secondary schools. Where this was in place, there was a greater coherence in the curriculum and sharing good practice was often intrinsic to planning.

6. **Key finding:** Too often, in planning science activities, teachers did not take sufficient account of what pupils had already learned at previous key stages and did not give them clear advice on how to improve their work further. As a result, pupils lost interest and made insufficient progress.

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[5] The National Curriculum requires students in Key Stages 3 and 4 to be taught about 'how science works', one of the four attainment targets. It consists of four components: data, evidence, theories and explanations; practical and enquiry skills; communication skills; applications and implications of science.

[6] Science Community Representing Education (SCORE) is a partnership between the Association for Science Education, the Biosciences Federation, the Institute of Biology, the Institute of Physics, the Royal Society, the Royal Society of Chemistry and the Science Council. SCORE acts under the auspices of the Royal Society and is chaired by Sir Alan Wilson FBA FRS. The report may be found at: www.score-education.org/publications.

[7] 'Getting practical' is led by the Association for Science Education. For further information, see: www.gettingpractical.org.uk/m1-9.php.

Update: It is clear from the scrutiny of assessment and tracking records in previous surveys and in the current one that teachers now know much more about the progress of individuals and plan for smoother transitions between years and key stages. Coherent records are passed on to the next teacher, reducing pupils' repetition of experiences in science.

7. **Key finding:** Most primary teachers had limited opportunities for continuing professional development to enhance their expertise in science, partly because their schools did not see the subject as a priority for development.

   Update: The Royal Society's report in 2010, *Primary science and mathematics education: getting the basics right*, made it clear that a very small number of primary teachers have a significant background in science or mathematics.[8] The report also described the findings of research that showed that primary teachers lacked confidence in teaching science and mathematics. It continues to be the case that there is insufficient, science-specific in-service training for primary teachers. Significant efforts have been made to increase the uptake of science, technology, engineering and mathematics (STEM) subjects at post-16 and at degree level, but a secure and engaging experience of science in the primary school is the foundation needed for successful science in the secondary school and beyond.

8. **Key finding:** In too many primary and secondary schools, teachers were mainly concerned with meeting narrow test and examination requirements and course specifications. This led them to work in ways that did not meet the needs of all pupils or promote independent learning.

   Update: This finding was made at a time when the statutory tests at the end of Key Stages 2 and 3 were in place. Since the last report, these tests have ceased. While the best schools had not been hindered by them, inspectors found that, in the schools visited, the absence of the tests had helped some schools to use their freedom more effectively and had led to considerable curriculum innovation at these key stages.

9. **Key finding:** The secondary schools visited were beginning to develop programmes of study that gave 14- to 19-year-olds access to vocational and academic pathways in science, suited to their needs and interests. However, progress in this area was too slow.

   Update: Provision has moved on rapidly during the period covered by this report. The large majority of the schools visited had provided a wider range of pathways for students aged from 14 to 19. These included GCSE courses in core science, additional science, additional applied science and triple science,

[8] *Primary science and mathematics education: getting the basics right* (DES1819), Royal Society, 2010; http://royalsociety.org/State-of-the-Nation-Science-and-Mathematics-Education-5-14/.

vocational science GCSE and BTEC science. More detail is given in the curriculum section of this report.

Achievement in science

Primary schools

10. In around one in 10 of the primary schools visited, pupils' progress was outstanding, and in around six in 10 it was good. In none of the schools visited was pupils' progress in science judged to be inadequate. The progress made was similar across the ability range of pupils, supporting the view that, in general, pupils were receiving science education that was appropriate to their needs.

11. Levels of attainment in science in the schools visited were broadly similar to those observed during the previous inspection cycle. This reflects the national picture, which is of standards in science in primary schools remaining largely unchanged over the last three years with a slight decline in the standards achieved by the most able pupils. In 2010, 89% of all pupils attained Level 2 or above at the end of Key Stage 1. However, there was a slight decline in the proportion of pupils attaining Level 3 or above to 21% over the period covered by this report. The picture at the end of Key Stage 2 is similar, with 85% of pupils in 2010 attaining Level 4 or above, the same proportion as in 2008. The proportion of pupils at Level 5 or above has declined slightly between 2008 and 2010.

12. Good progress and standards were most often associated with:

- good leadership and management
- effective continuing professional development
- the improved use of assessment
- a clear focus on science work that included a significant component of scientific enquiry and investigation.

13. In the majority of the schools visited, the pupils enjoyed science and, particularly, practical and investigative work. Overall, however, pupils made less progress in scientific enquiry and investigative skills than in their knowledge and understanding of areas of the science National Curriculum. In relation to knowledge and understanding, teachers' assessments indicated that pupils' highest levels of attainment were in 'life processes and living things', and their lowest levels were in 'physical processes'. In the schools where progress was satisfactory, opportunities for pupils to plan and evaluate their own investigative work were more limited.

Secondary schools

14. The progress of students in science was good or outstanding in around two thirds of the secondary schools visited. Progress was outstanding in one in six of the secondary schools compared with one in 10 of the primary schools visited. The progress of all groups of students in science was similar in around three quarters of the schools. In a few cases, there were differences in the progress of boys and girls and between students of different ethnic backgrounds, but in most of these the senior leadership team was aware of the differences and had plans to tackle them.

15. As in the primary schools, attainment in secondary schools was similar to that seen in the previous three-year period, although with some signs of improvement in Key Stage 3 with a rise of 4% in the proportion of students attaining Level 5 or above to 80%. There was a rise of 5% in students attaining Level 6 or above to 48% in 2010. There have been improvements in attainment associated with the greater diversity of provision in Key Stage 4. There has been a large increase in the number of pupils achieving A* or A grades at GCSE in 2010 in the order of 12,000 more for each of biology, chemistry and physics.

16. In around two thirds of the secondary schools visited, the introduction of a greater range of science GCSE courses had provided a better match of courses to individuals' needs, and the curriculum and learning in science had also become more focused on individuals. In the schools where courses were matched carefully to the needs of individuals, their records of progress showed improvement. This diversification had a positive impact on students' attitudes to learning and contributed to the increased number of A* and A grades achieved at GCSE in biology, chemistry and physics. Students who had chosen to follow triple science courses were often well-motivated and described how they found the work engaging and enjoyable.

17. In post-16 studies there has been an improvement each year in standards attained. Over the last five-year period, the proportion of students attaining grades A or B in science subjects at A level has risen by around 5%.

18. Many schools reported higher levels of engagement for students who followed applied science courses, particularly BTEC. Students and staff acknowledged that they had found the assessment requirements for BTEC manageable and better suited to many candidates because the students were continually aware of how well they were attaining and had a clear understanding of how to improve.

19. Schools entering large proportions of students for vocational qualifications such as BTEC have improved their GCSE-equivalent results. However, progression rates to specialist science courses from BTEC are very different from those for students completing GCSE courses. In 2009, the proportion of students studying the three sciences at GCSE who then pursued A-level science courses

was 46%. For those studying GCSE double science it was 9%, and for those studying the BTEC or GNVQ equivalent to two GCSEs it was 1%.

20. In the schools where progress was satisfactory, the opportunities for students to design and carry out experiments were limited; too much of the practical work was prescriptive, with students merely following instructions. These schools were often influenced too much by the specific ways in which practical work and scientific enquiry skills were assessed in Key Stage 4 for GCSE sciences and, as a result, were less concerned with providing opportunities for wider-ranging investigations.

21. The highest standards seen were in the schools where the scheme of work included well-integrated experiences of scientific enquiry and access to experiences that covered all aspects of 'how science works'. In these schools, students were involved in planning and carrying out regular science investigations, so that they understood the processes involved. It was this combination of procedural and conceptual knowledge that promoted the most effective learning in science.

22. Without such regular involvement in all aspects of 'how science works', students were less able to participate and learn actively. For example, when practical work was simply directed by the teacher, with no contribution from the students to planning it, their learning was less effective and they showed less evidence of developing their skills and knowledge. Students needed to participate in all aspects of investigation: forming hypotheses, planning, carrying out and evaluating practical work. Only following instructions from worksheets to complete a practical activity limited the ways in which they could contribute and how they benefited. Students' involvement was key to engaging them with science and thereby increasing their knowledge and understanding. Group work and class discussions, however, had to be well-organised in order to challenge them sufficiently.

23. Also associated with good or outstanding progress was the active involvement of students in peer and self-assessment. In around two thirds of the secondary schools visited, students were aware of their targets and how well they were making progress. The best schools promoted this by close monitoring of students and frequent reference to their performance in conversations between teachers and students. When this was focused on the needs of individuals, students most often responded positively. They described how well they were supported and how much they appreciated the efforts of their science teachers.

Quality of teaching in science

Primary schools

24. The overall quality of teaching in primary schools was similar to that in secondary schools but with a smaller proportion of outstanding lessons. Teaching was at least satisfactory in all the schools visited. It was good in just over seven in 10 of the schools, and outstanding in around one in 20.[9] This is a broadly similar picture to that in the last report. Part B of this report provides case studies of outstanding teaching and examples of how weaker practice might be improved.

25. In all the primary schools visited, teachers' subject knowledge was at least satisfactory. In the large majority of the schools, the teachers' knowledge and understanding of the National Curriculum science requirements were good or outstanding. Teachers had more concerns about their knowledge of physical sciences than that of living things. Limited expertise and confidence restricted the level of challenge that some teachers could provide for more academically able pupils. In around six in 10 of the primary schools visited, the science coordinator was effective in keeping other staff up to date about developments in the subject.

26. Planning to meet the full range of pupils' needs was at least satisfactory in all the schools visited and most teachers provided well for the needs of all the pupils in their class. In the lessons seen, planned activities generally related well to the objectives, and hands-on experiences stimulated pupils' engagement and enjoyment.

27. Inspectors found no evidence of improvements in teaching science in the primary phase that could be attributed to the Primary National Strategy which focused mainly on literacy and numeracy. This view was shared by most of the school leaders in the schools visited.

28. Teachers' use of ICT was good in nearly two thirds of the schools visited and outstanding in three schools. The teachers used ICT well to illustrate phenomena that the pupils could not experience first-hand. There were some good examples of ICT being used interactively, with pupils' responses being required to move the work forward. Inspectors saw examples of pupils' independent learning at computers using commercial programs, but these were not always sufficiently challenging. Inspectors saw very few examples of pupils using ICT to measure or record the outcomes of practical activities they had done.

29. Assessment generally was good or outstanding in about two thirds of the schools visited. However, the guidance provided by the Qualifications and

[9] The judgement was made in 91 of the 94 schools visited.

Curriculum Development Agency (QCDA) in 'Assessing pupils' progress' had not yet had a strong enough impact on schools' practice.[10] Inspectors saw pupils being involved in peer assessment and self-assessment in only around a third of the primary schools visited. Practice was consistently good in only one in 10 of the primary schools. In a greater proportion of schools, senior leaders had identified this as an area for development.

30. Marking was carried out systematically and was effective in around two thirds of the schools visited. Formative comments and some discussion in the most effective marking helped pupils to understand how they could improve their work. In the weaker schools, marking was inconsistent and did not let pupils know how to improve or where and why they had done well.

31. Setting targets for individual pupils had increased since the last three-yearly report, both in terms of quality and in the proportion of schools that were implementing effective systems for doing so. In one school, for example, pupils in Key Stage 2 had taken responsibility for keeping a record of their attainment and their targets. They had frequent opportunities to talk to teachers about the standard of their work and how to improve. These sessions were, effectively, target-setting meetings. Through self-evaluation and frequent feedback from teachers, the pupils knew how well they were doing and what they needed to do to improve. They were happy to take on this responsibility.

Secondary schools

32. The quality of teaching in the secondary schools visited was very similar to that in the primary schools, although with a slightly higher proportion of outstanding teaching. Inspectors did not judge the science teaching overall to be inadequate in any of the schools visited. Individual inadequate lessons were observed in a few schools. This is a positive picture compared to school provision more generally: science is a core subject and receives considerable focus; it has a strong subject association and learned societies for all the sciences; it is substantially taught by specialists and has significant funding for high-quality continuing professional development.

33. In around nine in 10 of the secondary schools visited, the planned activities were linked effectively to the learning objectives of the lesson. The schools in which students' progress was good usually provided varied and engaging activities in science, such as:

- presentations by students
- practical and investigative work
- research projects

[10] 'Assessing pupils' progress' is a national approach to assessment, designed to support teachers in making judgements on pupils' progress. For further information, see: www.qcda.gov.uk/assessment/82.aspx.

- use of models, such as those showing how systems carry out a function
- demonstrations
- interactive use of ICT video clips and other media resources
- activities where students put a set of cards in sequence to describe a process or observed phenomena
- group discussions.

34. In these schools, teachers were enthusiastic; they gave lively explanations and managed students’ behaviour effectively. They were reflective, keen to improve and used relevant contexts for work in science. In contrast, in the lessons that were no better than satisfactory, the teachers often talked for too long, were poor at managing time in the lesson, and provided insufficient challenge or did not provide for the range of students’ needs.

35. Good-quality practical work was a key feature of good teaching in science. However, it was effective only when it was well-planned and managed. Simply exposing pupils to practical work did not, in itself, promote learning, as this example illustrates:

> A teacher introduced her Year 7 students to the practical work, using the words ‘macerate’, ‘extract’, ‘mortar’, ‘pestle’, ‘indicator’, ‘pH’, ‘acid’, ‘alkali’ and ‘filtration’ in her description of extracting vegetable colour from a beetroot in order to determine whether solutions were acid or alkali. She gave the students a worksheet that described what they needed to do. They were required to fill in missing words in the gaps on the worksheet. One girl, when asked by the inspector what she was doing, said, ‘It’s a bit like cooking.’ She mashed her beetroot into a pulp and carried out the instructions on the worksheet but could not describe why she was doing each stage of the procedure. She was aware she had to fill in the gaps and set about doing so by asking the teacher or copying from others. She almost completed the gap-filling but could not say why she had used the words in each gap. At the end of the lesson she, and many others who were asked, did not understand what they had done and why. Their grasp of the new vocabulary was very shaky. The students had, in the words of one, ‘done things with stuff’ but had learnt very little.

This contrasts with the highly effective practical and investigative work that took place in the lesson described below.

> Year 8 students were completing a unit of work on acids and alkalis that had involved them in research on the effect of acid rain on limestone. They had worked in groups to generate their own questions to pursue. Many of them had taken the time to form hypotheses and had planned and carried out their own practical work. The students had presented the outcomes of their research to the class in the form of high-quality

PowerPoint presentations. Discussion with the students showed how varied these presentations were.

At the end of the final presentation, the teacher invited the presenter to stay at the front of the class and to use the computer to gather the data from the investigations. Using the wireless laptops, each group transmitted its tabulations of data to the teacher's computer and the student displayed these on the interactive whiteboard. As soon as data started appearing, the students began to spot anomalous figures, compare patterns of data, summarise trends, account for differences, evaluate data and suggest improvements. There followed a rich time of discussion and clarification that allowed students access to the ideas and work of others and to build their own knowledge and understanding, not only of the chemistry but of the way that science works.

36. The effective use of ICT was having a positive impact on attainment in science in nearly two thirds of the schools inspected. In the schools where the impact was only satisfactory, this was often because ICT was being used predominantly by the teacher to show information. The students in these schools were not given sufficient opportunity to use ICT for themselves.

37. The very best use of ICT involved students participating actively. Electronic whiteboards were used interactively and banks of laptops had made it possible for them to be used for work that was integral to laboratories, getting around the need to relocate classes to ICT rooms. Students used laptops for a range of purposes and applications, including:

- data logging
- internet research
- simulations
- word processing
- presentations
- digital images
- access to virtual learning environments.

However, there were very few schools in which the science teachers and ICT staff collaborated to plan for progression or to pool their assessments to allow progress in ICT to be tracked.[11]

[11] This finding echoes an earlier report on ICT: 'In the majority of the [177] primary and secondary schools visited, teachers did not evaluate specifically how well pupils and students applied and used their ICT skills when working in other subjects.' See: *The importance of ICT: information and communication technology in primary and secondary schools*, *2005/2008* (070035), Ofsted, 2009; www.ofsted.gov.uk/publications/070035.

38. In nine in 10 of the schools visited, the teaching met the range of students' needs, in broad terms. In other cases, there was insufficient differentiation of the work to challenge all students, particularly those who were higher-attaining. More than one third of the schools visited attributed some of the improvement in their practice, such as in assessment for learning and planning lessons, to the work of the Secondary National Strategy.

39. In all the secondary schools visited, the science teachers' knowledge and understanding were at least good overall, although not all science lessons were taught by science specialists. This was particularly true of physics and, to a lesser extent, chemistry. Inspectors' observations of lessons during the period of this survey support the findings of the previous three-year report that the better the specialist match of teachers to the curriculum, the higher the achievement of students.

40. The recruitment of graduates to train as teachers through the Graduate Teacher Training Registry (GTTR) has been reduced in 2010 for almost all secondary subjects. However, the notable exceptions are physics and chemistry, shortage subjects within the sciences, which have seen increases in recruitment against the overall trend. Over the period 2008 to 2010, there has also been an increase in the number of applications for entry to university to study STEM subjects including biology, chemistry and physics. There is, therefore, the possibility of an increased recruitment of specialists to teach science in the future.

41. In around three quarters of the secondary schools visited, the teachers had attended courses provided by awarding bodies, for example those relating to new specifications for GCSE and A level. Around three quarters of the schools also provided continuing professional development for science teachers, but on generic issues such as improving teaching and learning or assessment. Where such training was carried out, teachers responded positively and put the training into action in the classroom.

42. Good assessment usually accompanied good teaching. Good assessment by teachers and students showed areas for improvement clearly; teachers were able to plan work and intervene to enable individual students to make progress. Part B of the report gives examples of outstanding practice.

43. In more than a third of the schools visited, the students were involved effectively in peer and self-assessment. In the remaining schools, developments were at an early stage. Peer and self-assessment strongly promoted students' understanding of the standards they had reached and how they might improve. This knowledge of their performance also built their self-confidence and motivated them to do better.

44. In around two thirds of the schools visited, effective marking helped the students to understand what they had done well and provided feedback on what they could do to improve. However, the quality of marking often varied;

this had an impact on students' progress. In around one quarter of the schools, marking was inconsistent, as was the quality of the feedback that students received. These schools often lacked a clear policy backed up by rigorous monitoring. The implementation of the 'Assessing pupils' progress' initiative was at an early stage and inspectors saw very few examples of good practice in this area in the final year of the survey.

The curriculum in science

Primary schools

45. In around four in five of the primary schools visited, the curriculum in science was good or outstanding, a similar proportion to that in secondary schools. It was outstanding in just under one in 10 primary schools compared to just under one in seven secondary schools. The activities that were planned supported pupils' progress in their knowledge and understanding of science, and allowed them to develop their science skills in increasingly demanding situations. This concern for progression was less evident in the less effective schools, particularly in science skills, and pupils had fewer opportunities to plan and carry out investigative activities.

46. In the very large majority of the schools visited, science was taught regularly each week. This regular exposure to, and consideration of, phenomena through scientific enquiry was important in building pupils' skills and confidence. The development both of skills and confidence promoted the pupils' increased knowledge and understanding of science.

47. Although, increasingly, scientific enquiry was being planned into schemes of work for science, its assessment was not developed well across all the schools visited. There was less planning for different needs in scientific enquiry than there was in knowledge and understanding, where the content was usually matched well.

48. The science curriculum was often planned collaboratively and with the pupils' development in other areas of the curriculum clearly in mind. This collaboration incorporated pupils' development in literacy, numeracy and appropriate areas of other National Curriculum subjects. Teachers in the primary schools visited talked confidently about how the different parts fitted together and this led to some very effective provision. The schools that used a strong team approach for planning could often show evidence of pupils' increased engagement and progress as a result. However, the challenge of communicating with other teachers and schools to ensure pupils' smooth transition between key stages remained. Weak communication and poor continuity between teachers and schools meant that pupils' learning faltered as they met work that they had done before.

49. Enrichment and extra-curricular activities had a positive impact on pupils' attitudes to science. These were strong in the schools in which the pupils'

achievement was good or outstanding. The schools often used their school garden or local environment effectively. As well as the enjoyment they had from growing and eating their own vegetables, pupils showed empathy for living things and grew to understand their interdependency in ecosystems. Pupils also benefited from the knowledge of visiting experts. Activities centred on, for example, birds of prey, dental hygiene and recycling all contributed to pupils' positive engagement. However, there was scope to extend the range of extra-curricular activities to include more work on the properties of materials and on physical processes.

50. The best practice in the Early Years Foundation Stage involved a good range of activities, many of which were practical. In most cases, the schools had a well-planned and balanced programme of activities. There was a greater emphasis on life and living things than on the physical sciences. Teachers said that this was because the area of study 'Knowledge and understanding of the world' gave a higher priority to living things. This predominance persisted into Key Stage 1 where teacher assessments showed pupils' attainment to be highest in life processes and living things, then materials and their properties, followed by physical processes and, finally, scientific enquiry. Emphasising experiences that promoted exploration, either suggested by the teacher or by following children's ideas, provided a good foundation for developing their scientific enquiry skills. However, this was not followed up consistently in Key Stages 1 and 2.

51. The previous science report noted that many schools used the schemes of work published by the Qualifications and Curriculum Development Agency as a basis for their curriculum plan for science. Over the last three years, the most successful schools have adapted their schemes to match their pupils' needs and to reflect their locality and environment more effectively. In primary schools, the curriculum was increasingly thematic; science was taught less as a discrete subject and more as a key component in a unit of work. Where the planning ensured coverage of the National Curriculum and combined learning from other subjects, time was used more efficiently. In one of the schools, for example, the scheme of work for science was based on activities in which science was integrated with components from other subjects. Additionally, a block of several days in each half-term was allocated where science was the focus, but with other subjects planned in where relevant.

52. Since the removal of the requirement for national testing in science at the end of Key Stage 2, some schools have felt able to plan provision for science in a more varied way that pupils found engaging and enjoyable. Consequently, in the schools that have taken the opportunity to remodel the curriculum, Year 6 pupils have been able to continue with a good range of challenging science activities rather than, as happened too often before, being restricted to revising the science they had already done.

53. In the schools where the curriculum was no better than satisfactory, more needed to be done to ensure better-balanced and relevant content, and more effective development of knowledge, understanding and skills.

Secondary schools

54. In 56 of the 94 secondary schools visited, the curriculum was good, with another 14 in which it was judged to be outstanding.

55. Inspectors saw the most effective provision when those teaching the science curriculum planned it collaboratively. Not only did this gather the best ideas from the team, but it also provided a forum for sharing good practice. Where there was a culture of 'plan, do and review', innovation by teachers was encouraged and further improvements were made readily. In this environment, schemes of work often built in cross-curricular elements, such as literacy and numeracy. Similarly, links to other subjects were developed more readily and effectively. The quality of cross-curricular planning was generally not as strong in the secondary schools visited as that seen in the primary phase. However, where such planning was done well, students benefited in their understanding of the part that science plays in society.

56. The range of extra-curricular activities seen in the secondary schools was broader than that in the primary schools, but the activities did not usually engage large numbers of students. As part of the STEM initiative, funding was provided to support STEM clubs. These allowed students to explore, investigate and discover STEM subjects in a stimulating learning environment, away from the constraints of the school timetable or a prescribed curriculum. They encouraged students and their club leaders to work together and explore many different ideas and activities. These involved practical experiments, investigation, discussion and reflection. Most of all, they were engaging and stimulating. They motivated and built confidence in young people who struggled with STEM subjects and also provided an extra outlet for students who already showed aptitude and were interested in furthering their learning.

57. The number of schools planning for a two-year Key Stage 3 beginning in Year 7 had increased since the last report. Often these schools expressed the aspiration to make Key Stage 3 more engaging and relevant for students. They had scientific enquiry and skills development as significant components of the curriculum. These changes promoted high-quality curriculum content that was taught well. Through their monitoring of students' progress, the schools were often able to demonstrate higher achievement. However, in the schools where the time frame for Key Stage 3 was shortened to two years without effective curriculum planning and a focus on good teaching and learning, the levels of students' engagement and enjoyment were lower.

58. An important reason for a two-year Key Stage 3 was to have an extended period of time, up to three years, to teach GCSE sciences in a more enriched way. Schools making the most of this opportunity were able to ensure greater engagement and relevance to students. They planned to avoid excessive didactic teaching, and to ensure that the students experienced 'how science works'. This development ran in parallel with the schools moving further into

monitoring the progress made by individual students and ensuring greater challenge for them.

59. Since the last report, the range of courses made available to students in Key Stage 4 has increased and, in most of the schools visited, this had led to a diversification of the curriculum to meet the needs of all students more effectively. Table 1 highlights recent changes in the number of students in all types of schools following particular science courses.

Table 1: Entries to science courses in all secondary schools between 2008 and 2009

Entry numbers	2008	2009	2008-09 change	% change
End of KS4 cohort	653,083	634,507	-21,065	-3%
Triple science	64,340	80,000	15,660	24%
Core and additional Science	350,300	321,500	-28,800	-8%
Core and additional applied science	49,800	46,000	-3,800	-8%
Core science (single entry)	85,600	87,000	1,400	2%
Applied science (vocational GCSE)	20,200	18,600	-1,600	-8%
BTEC science	20,100	30,000	9,900	49%
Engineering (vocational double award)	6,400	5,100	-1,300	-20%

Data from Department for Education internal analysis.

60. The large percentage increase in triple science entries shown in the national data is particularly notable. There was an even larger increase in entries to BTEC science over the same period. Fifty per cent of maintained comprehensive schools offered their students triple science in 2009 compared with about 30% at the time of Ofsted's last triennial report on science. In 2009, 29% more students in maintained schools were entered for triple science than in 2008 and it was expected that the proportion would continue to increase. All science specialist schools were required to offer triple science courses and the Specialist Schools and Academies Trust expected close to 100% of schools to comply in 2010, compared with 78% in 2009. The increase in the number of students taking triple science has undoubtedly been promoted by the entitlement introduced by the then Secretary of State. This set out to give all students attaining Level 6 in science at the end of Key Stage 3 the entitlement to choose to study the three separate sciences in Key Stage 4. However, the extent to which the schools visited were securing this indicated that the entitlement is not yet universal.

61. In many cases, particularly where students studying triple science were allocated time for three subjects in the curriculum, inspectors found this was leading to higher levels of interest and motivation. Double award science has equipped students with the necessary knowledge, understanding and skills to study science at A level. However, data from the Department for Education and qualitative evidence from inspection visits suggest that students who study three separate sciences are more likely to choose to study science at A level and beyond.

62. Most schools required the majority of students to follow courses leading to at least two GCSE awards in science, with options available from core science, additional, additional applied, and triple science. But, in increasing numbers of schools nationally, vocational courses were also available, and the substantial proportional increase of entries for BTEC science from 2008 to 2009, shown in Table 1 above, was reflected in the schools visited.

63. Some students were well suited to vocational courses. They benefited from frequent assessment and feedback against criteria that guided their improvement. They clearly liked knowing how well they were doing and showed increased self-confidence. However, in a few schools, large proportions of students, or even the whole cohort, were entered for BTEC science, with an associated rise in GCSE-equivalence point scores for the schools. This approach meant that some students were not able to access the more academic courses that would have matched their ability and aptitude more effectively.

64. As seen in a small number of schools, other curriculum models, although benefiting the majority of students, also limited opportunities for other students. For example, in one school visited, all its students started triple sciences GCSE courses in Year 9. This had the advantage that triple science could be provided over three years, using just 20% of curriculum time in Years 10 and 11. There was some flexibility in that students who were finding triple science hard to cope with could change to courses leading to two GCSEs in science in Year 11. However, no vocational science option was available to students in Key Stage 4 and, as a result, the school was not providing the most suitable science courses for the whole ability range. The teaching of triple science in Years 9 to 11 had increased the number of students choosing to follow sciences at A level, but there was no vocational science provision post-16. In some other schools visited, students could follow vocational courses at Key Stage 4, but no vocational science courses were provided at the school post-16.

65. In another example, the school visited had not developed a sufficiently flexible science curriculum at Key Stage 4. It was the school's intention to introduce triple science for all students in September 2010 after a two-year Key Stage 3. It believed that a diversity of courses was not necessary as the science teachers were skilled at differentiating courses for the full ability range. This view was not shared by inspectors and some students spoke negatively about their lack of choice, with all the students being required to follow the same course.

Inspectors judged that this provision did not meet the needs of all students and that the school's aspiration of triple science for all was unrealistic.

Leadership and management

Primary schools

66. In around three quarters of the primary schools visited, overall leadership and management of science were good or outstanding and in 13 schools they were outstanding. The strong collaborative culture of some primary schools promoted the sharing of good practice and the effective pooling of resources and ideas. Innovations could be captured readily and shared with colleagues. However, the frequency with which some headteachers moved responsibilities for the coordination of subjects created problems in some cases, and the short tenure of the role of the coordinator restricted what could be achieved and sustained.

67. When the responsibility for science was changed, professional development was rarely provided to prepare teachers for their role as coordinator. Less than half the subject leaders interviewed said that they had received training for their leadership role. The strength of support received, for example from the local authority, varied greatly from authority to authority. In around three quarters of the primary schools, science subject leaders felt that the school's senior leadership was providing a good balance of support and challenge. It was clear that much of the effective development of teaching and learning had been done as a whole school, with senior staff providing much of the input.

68. In around half the primary schools visited, subject leaders monitored and evaluated provision well through activities such as lesson observations. This is a key mechanism for improving teaching and learning. In the remaining schools, where monitoring did take place it was less frequent and often did not involve observing lessons. The most common ways of monitoring were through data analysis and the scrutiny of pupils' books, but these activities varied a great deal in the frequency and thoroughness with which they were done. Monitoring was particularly effective where there was a constructive dialogue between the colleagues monitoring the standards and those being monitored. The tracking of progress in pupils' skills of scientific enquiry was a strength in only a minority of the schools visited.

69. Subject leaders had provided science-specific training for staff in around four out of five of the primary schools visited. The training that had taken place in some schools had improved teachers' understanding of science and particularly their understanding of scientific enquiry. However, science coordinators were often not trained as science specialists and this could limit the range of training that they were able to provide. The take-up of sources of science-specific continuing professional development from outside the school was very low at around one in 10 schools. The lack of external professional development was reported in the last three-yearly report and the situation has not improved since

then. Few of the headteachers showed awareness of developmental provision in science, such as that offered through the network of Science Learning Centres.[12]

Secondary schools

70. The quality of the leadership and management in science was good overall in more than four out of five of the secondary schools visited. In around one in five of the schools, leadership and management were outstanding and were having a very positive impact on teaching, learning and students' achievement. Again, this is a higher proportion than in the primary schools visited. Common features in these schools included:

- clear systems for tracking the progress of individual students
- effective intervention and planning informed by the tracking data
- collaborative planning and sharing of good practice
- clear roles and responsibilities
- the setting of clear standards for the quality of teaching.

71. This example illustrates many of the factors associated with good leadership and management.

> A well-managed science department engaged in effective self-evaluation, which took account of the views of all major stakeholders. It meant that the head of department had a good understanding of the subject's strengths and weaknesses and demonstrated a good track record of making improvements, including dealing with the issues from the last inspection. The department's robust monitoring and evaluation system tracked the progress of individual students and was used as a basis for planning and interventions. The department had a common vision for the inclusion of all learners and was effective in pursuing this and dismantling barriers to engagement.
>
> The department was well-organised on a day-to-day basis and used resources well, including out-of-school opportunities, to improve outcomes for students and to secure good value for money. It promoted good links with parents and outside agencies to support its work. A training programme focused on the aspects of science which teachers found to be most problematic. The departmental science handbook included guidance on the principles of good teaching and learning, and policy and procedures for assessment to inform planning and target-setting. Subject

[12] The aim of Science Learning Centres is to improve the teaching of science and to inspire pupils by providing professional development for teachers. There are nine regional centres in England and one national centre, each with a number of satellite centres. For further information, see: www.sciencelearningcentres.org.uk.

specialists had collaborated to create a scheme of work in which a good range of learning activities and the development of skills in science enquiry and 'how science works' played a significant part.

72. The most important indicator of weak leadership, observed in a small minority of the schools visited, was a failure to challenge the practice of less effective teachers. In these schools, the result was usually the underperformance of the students in the classes taught by those teachers.

73. Nine out of 10 of the schools visited were setting themselves challenging targets in science. In just under half the schools, staff were able to show the positive impact of these targets in raising attainment. In two thirds of the schools, the monitoring of standards in science was systematic, although the quality of the procedures varied considerably. In the schools where leadership and management were good or outstanding, the head of department had an accurate and balanced view of strengths and weaknesses and had clear plans for improvement.

74. The tracking of students' progress has improved and took place in all the secondary schools visited in the last of the three years covered by this report. All but a small minority of schools used the tracking data to identify underachievement. Progress in scientific enquiry and the skills of 'how science works' were tracked less effectively than progress in the areas of the National Curriculum for science concerned with knowledge and understanding. Knowledge of the progress made by students and their attainment were generally being passed on to the next teacher through coherent records. This was reducing the repetition of science experiences for students and contributed to smoother transitions between classes and key stages.

75. In around half the secondary schools, self-evaluation carried out by the science department had led to clear improvements. However, around one in five of the schools visited conducted self-evaluation where the findings were not used effectively to secure improvement.

76. The heads of department of four out of five of the schools visited believed that they had received an appropriate balance of challenge and support from their senior leadership team. A large proportion of the science departments had a designated link member of the senior leadership team; many heads of department submitted reports to the governing body and were subject to questioning on their performance. In a small minority of the schools, the senior leadership team did not challenge the science team sufficiently to promote greater improvement. These leadership teams did not have a well-evidenced and coherent view of the science department's strengths and weaknesses and so were not in a strong position to challenge it.

77. In the last year of the three-year inspection cycle, only one in five of the heads of departments visited had received subject-specific training on leadership and management. Training had a positive impact on the confidence of heads of

departments who also reported that they had gained a clearer understanding of issues such as effective communication, collaborative working, and monitoring and evaluation. It was also evident from inspectors' discussions with heads of department that subject-specific training had promoted a more coherent and broader understanding of issues affecting standards.

78. More secondary than primary teachers in the survey had received appropriate professional development. While four out of five secondary science departments felt that the professional development they had received was satisfactory, only one in five thought it was good. The quality of professional development received from external providers was variable but that provided by the national network of Science Learning Centres was consistently reported to be good. Part B of this report provides more information about these centres. Much professional development was provided within schools, but this was mainly generic, on topics such as assessment for learning.

79. Where teachers had attended externally provided subject training, evaluation of the impact showed improved teaching and a sharing of good practice in their department. However, a lack of science-specific courses was limiting the capacity of some staff to bring about improvements. Travel time, travel costs and costs of teachers' absence were all given as reasons for limiting the use of external course providers.

Part B

Post-16 science in schools and colleges

80. Throughout the period covered by this report, schools, sixth forms and further education colleges were inspected to different frameworks, although these frameworks were aligned from September 2009 to ensure that post-16 judgements were comparable. Evidence on post-16 science in schools has come from survey visits in which the sixth form work was considered as part of the total provision for the age range 11 to 18. In further education colleges, including sixth form colleges, science was inspected as an area of focus in a proportion of full college inspections. As a result, it has not been possible to make direct comparisons between all aspects of science education in schools and colleges.

81. Generally, further education colleges catered for students of a wider range of ability than those in school sixth forms. Science provision in schools was predominantly at level 3, that is, GCE AS and A-level courses, although with an increasing proportion of vocational science courses. Some colleges provided level 1 (foundation) and level 2 (intermediate), as well as level 3 courses, often with extensive vocational programmes. The number of students following science courses in a school sixth form was generally lower than the number of students doing so in a college.

82. Science was inspected in 31 colleges in 2009/10, under the new Common Inspection Framework. It was good or outstanding in 15 of the colleges; it was satisfactory in 11 and inadequate in five. The proportion of inadequate science provision was similar to that found during the previous cycle of college inspections from 2005 to 2009. This proportion of inadequate provision is a matter of concern. No other post-16 curriculum area in colleges was judged to have such a high proportion of unsatisfactory provision.

83. Where science was judged to be good in colleges, inspectors identified the following key strengths:

- achievement and standards at intermediate and advanced level were high
- students were confident and competent in practical work, using specialist equipment safely and effectively
- science teachers worked well in teams and planned interesting and engaging lessons with a good balance of practical work and theory
- skilfully managed discussions allowed science teachers to assess students' progress informally and to develop students' confidence
- the science teams were led well and had a strong collective emphasis on improving the quality of teaching and learning and raising standards.

84. Where science was judged to be inadequate, the following weaknesses were evident:

- outcomes for students, both in terms of pass rates and progress, were poor
- recruitment processes were insufficiently careful
- levels of attendance and punctuality were low
- teaching was dull and uninspiring, using a narrow range of learning activities that did not meet the students' needs
- teachers routinely used ICT in lessons but the students did not
- target-setting for students was poor
- in some colleges enrichment activities for the sciences were insufficient
- science courses at foundation and intermediate levels were underdeveloped and progression routes to advanced courses were not clear
- curriculum management was weak and did not focus enough on improvement strategies.

85. The example below, from a large sixth form college, illustrates what outstanding science can look like.

> The college, in an inner-city area, recruits mainly but not exclusively from highly deprived areas. Pass rates in the sciences are very high and students' progress is well above that predicted from their prior attainment.

Team working among science teachers is highly effective and curriculum management is excellent. A safe, reflective ethos has been developed which allows teachers to be self-critical and to make sensible and realistic improvement plans. Close working between the highly skilled technical support staff and the teaching staff allows the teachers to concentrate on improving learning.

Teaching is both interesting and challenging. Science lessons are very well sequenced. They are linked effectively to extension activities for the more academically able students and additional catch-up sessions for those who are making less progress. The students are fulsome in their praise for the effectiveness of the extra help that their science teachers give them, which includes referral to appropriate support for literacy, numeracy and study skills. Assessment of students' work and progress is very strong; specific written feedback focuses on how students can improve. Online learning plans and target-setting are used thoughtfully to encourage students to reflect on their progress and set realistic targets for improvement.

A wide range of enrichment activities, including field trips and visits to higher education institutions, is instrumental in encouraging and enthusing the students. As a result of the high attainment and raised expectations, a good proportion of the students apply successfully to courses such as medicine, dentistry and physiotherapy. The college's science departments contribute in no small measure to its ethos as a whole and this brings out the best in the students.

86. Most of the strengths and weaknesses set out above were also features of provision in school sixth forms. Inspection evidence from school sixth forms, however, points to less inadequate provision, although a contributory factor may be the size and nature of the cohorts of students recruited.

87. Nationally, the proportion of students achieving A or B grades at A level has improved steadily since 2004/05 for all science subjects. This increasing success correlates with an increase in standards recorded by inspectors in sixth form lesson observations. Over the period of the survey, the quality of teaching observed in the sixth forms visited improved as teachers took lessons learnt about raising standards in Key Stages 3 and 4 and transferred them to their post-16 teaching. This compares with previous evidence that, while schools adopted strategies for raising standards suggested by such agencies as the Secondary National Strategy, they continued with more didactic and less imaginative methods in the sixth form. The shift in practice may be characterised by less note-taking and more note-making; that is, a shift in emphasis from teachers giving notes to their students to creating activities that require students to engage actively with their studies. The use of a wider range of experiences helped to increase students' knowledge and understanding. The shift in ways of working also coincided with changes to A-level specifications.

Teachers had encouraged greater activity from students as part of their responses to these changes.

88. The good practices in Key Stages 3 and 4 that were transferred to sixth form work included more rigorous target-setting and frequent assessment. Schools had closer monitoring procedures than those visited previously, leading to intervention with students who were falling behind in the standards predicted for them. Rigorous target-setting and regular monitoring of progress were also important features of good science education in colleges.

89. During the period of this survey, the number of students following A-level courses in physics and chemistry increased nationally. Numbers in biology increased initially but they showed a slight drop from 2008 to 2009. Most of the schools visited offered biology, chemistry, physics and psychology at AS and A level. Also during the period of this report, the number of courses available for sixth form study increased with the introduction of vocational science at A level. In schools where the GCSE offer had diversified to include vocational GCSE, some of the schools had secured post-16 pathways for students by introducing the vocational A level. Others, often because of limited staffing and resources, had not been able to do this. In such cases, care needed to be taken in offering students appropriate advice, information and guidance to ensure their progression to post-16 courses being provided by other schools and colleges. The example below is of a school improving the provision for its students.

> Over recent years, the curriculum in Key Stage 4 has been diversified to provide a good range of courses to meet the needs of students and establish a secure basis for sixth form education. Students can follow AS and A2 courses in biology, chemistry and physics. The school also provides a vocational pathway in BTEC First Diploma in science and is planning a vocational course that would lead to qualifications equivalent to AS level. The school is promoting greater consistency in assessing students' work to provide them with guidance on how to improve. It is ensuring that the curriculum choices of students in Year 9 are consistently well-informed and include the range of courses available during the sixth form and beyond. The introduction of a successful transition project enables students to move from Key Stage 4 to the sixth form more securely. The initiative is helpful, particularly to the 50% of students who join the sixth form from other providers. Good enrichment, through well-contextualised science and the STEM club, contributes to the recruitment of students to post-16 science.

Recognising the outstanding

90. This section of the report exemplifies outstanding science lessons. The text is taken from inspectors' direct observations of lessons and the examples cover a range of topics and year groups.

91. Primary example 1: Reception class

During their time sitting on the carpet, the teacher engages the children in describing the mini-beasts they had seen in their investigation of the school's grounds. In pairs the children talk about their mini-beasts and then share their ideas with the whole class. The teacher brings the teaching assistants into the conversation and they remind the children of their experiences. This helps them to arrive at an understanding of the wide range of living things in their environment. A sense of ownership and care for the environment is generated.

The teacher shows a video of a butterfly and its way of life. The presentation is interactive on the whiteboard and teacher skilfully uses questions and the children's answers to establish what was alive during the observation and the characteristics of living things. The children's level of interest and engagement is very high.

The teaching is animated and enthusiastic and the teacher has a detailed knowledge of the needs of individual children. She shows the class the caterpillars that they observed during the previous week and the children can see how much they have grown. Careful prompts from the teacher are effective in helping the children cooperatively to relate the characteristics of living things to their observations of the caterpillars. During this time the teacher works with individuals or small groups to promote further thought to extend their learning. The teaching assistants are similarly engaged in a purposeful way.

A session of summarising questions and answers leads to pupils demonstrating the caterpillar/butterfly life cycle to reinforce their knowledge and understanding. A child is dressed in a cagoule to represent the 'skin' of the caterpillar and is then wrapped in toilet paper to represent the cocoon. When the pupil breaks out of the cocoon the back of the costume shows the wings of the butterfly. To reinforce the learning, the teacher then takes on the role of the child and the pupils become the teacher in explaining the life cycle of the butterfly.

Key features

- high levels of engagement
- vigilance from the teacher in monitoring progress
- very good use of guided discussion between children
- very effective questioning to elicit ideas, to engage pupils and check understanding

- very clear progression of ideas; a very well-planned sequence of learning.
- good individual intervention and extension
- very effective class management, including the deployment of teaching assistants.

92. Primary example 2: Year 3

The lesson begins with an effective question and answer session in which pupils describe what they know about light. This clarifies the pupils' understanding of key vocabulary such as 'translucent', 'opaque' and 'transparent'. There are high levels of response, application and attention.

The teacher uses a penguin puppet to ask about shadows of objects in relation to an overhead projector, discussing size, shape, position and clarity. The pupils have recently been learning about energy and how the environment can be harmed by the poor management of energy. A pupil comments on the heat from the overhead projector and the teacher takes the opportunity to consolidate the pupils' thinking on energy and conservation; not wasting electricity; noise and heat as waste energy from such devices; and the dangers of overheating by poor use.

More discussion follows on what can be seen or not seen in a shadow, and talk of shades of grey, not just black and white, shows that light is dispersed in the atmosphere. The pupils then move around a series of well-planned and well-resourced activities at different stations in the room. Pupils' levels of application and good collaboration are very high. The teacher is very effective at monitoring progress and managing activities so that all the pupils visit all the work stations, consolidating and extending their knowledge and understanding of light.

Key features

- very good classroom management, combined with very good relationships, result in high levels of application
- effective explanations
- excellent questions used to check understanding, promote thinking and engage pupils
- very careful and effective development of vocabulary and its accurate use
- the creation of a positive environment for learning science.

93. Primary example 3: Year 5

Pupils collaborate well on an investigative task about friction. They are working on the question, 'Which is the best shoe for gripping the floor?' Pupils have been planning their investigation, taking decisions on what to measure, the equipment needed and the procedures they will carry out. The teacher has worked with the teaching assistant to plan and anticipate the range of activities that might be proposed. The assessment strategy for the activity was also agreed with the teaching assistant. The teacher and the teaching assistant have considered the 'knowledge and understanding' content of the activity and the science skills, such as the consideration of variables and the need for accurate measurement. The pupils work in groups of four and discuss their plans.

Discussions with pupils show that they understand fair testing clearly and can describe why they chose to carry out the investigation in the way they planned. Their attitudes to science work are very positive. They cite 'doing practical' as one of the things they enjoy most. They have considered the different surfaces on which they do not want the shoe to slip. They demonstrate their understanding of the need for accuracy and the purpose of repeating procedures and measurements to raise reliability. They choose a scale for measurement that will be most appropriate and they agree on their roles in the procedure.

Overall, the groups investigate a good range of variables and measurements and the outcomes are shared effectively with others. The process is very well managed by the teacher. A plenary discussion demonstrates the pupils' good and developing knowledge and understanding of forces, friction, surface area, changing mass to change force, and the range of variables considered.

Key features

- a very well-planned lesson in which the teaching assistant was fully aware of lesson objectives and assessment goals
- teacher vigilant in monitoring progress
- excellent collaboration; pupils take on roles and work constructively with each other
- pupils were taking decisions rationally and with understanding of scientific enquiry
- pupils were planning confidently and were selecting appropriate equipment; they were not simply following instructions: they knew what they were doing and why
- very good assessment procedures, coordinated between teacher and teaching assistant
- procedures carried out accurately: the pupils understood the need to repeat measurements and calculate averages to make the findings more reliable

- a very effective plenary session, in which the pupils were learning from each other's work, leading to good understanding of the range of knowledge elicited by this practical work.

94. Primary example 4: Year 6

The pupils' behaviour is excellent, they are engaged well. The teacher teaches enthusiastically and confidently through a well-planned lesson. She uses ICT effectively to illustrate a view of the future as she sets the scene to learn about evolution. The simulation shows the world in five million years' time.

She uses questions and answers well, with many of the questions directed at individuals for specific reasons: keeping attention, building self-confidence, encouraging, and checking understanding. She explores ideas such as plate tectonics through the effective ICT presentation. Evolution and adaptations are talked about with high levels of interaction with pupils. They make suggestions and answer questions confidently.

Pupils then carry out a 'beak experiment' very successfully. They use forceps of different shapes as model beaks to tackle four different samples of living things: small seeds, walnuts, apples, worms. They work in groups and their enjoyment of the activity is very evident. They discuss spontaneously how the shape of the beak affects what they can do with it and hence affirm the ideas of adaptation, the shape of the beak affecting how successful they were at feeding on particular food items.

Finally, pupils watch a video of an evolving lizard that lives on the salt flats, catching flies on its frills and so on. Pupils not only enjoy the video but they readily identify the key features of the lizard and how these help it to survive in that environment.

Key features

- a very well-prepared lesson
- very confident and enthusiastic teaching
- a well-sequenced series of activities that engaged pupils effectively
- imaginative practical work that built skills, knowledge and understanding effectively
- very good-quality resources including well-researched and relevant video clips.

95. Secondary example 1: Year 7

A very enjoyable and engaging starter activity involves the class in calling out the names of electrical components represented by symbols on flash cards. This not only reviews previous learning but introduces new symbols effectively in preparation for other tasks in the lesson.

The teacher carefully explains the objectives of the lesson. She describes electrical current and its unit, the ampere, using a PowerPoint presentation during which she elicits the students' own ideas; for example why the unit was represented by a capital A. The teacher gives a very clear description of the practical procedures and checks students' understanding by effective questioning and answers. The description is very detailed and draws on students' contributions; this results in very secure understanding. The practical work involves series and parallel circuits. Some students predict less current in the parallel circuits compared with that in the series circuits; others are challenged to agree or to make other predictions.

The practical work that follows demonstrates good understanding of the underlying theory. The students apply themselves well and there is no off-task activity. Good collaboration ensures successful practical work and students' full involvement. The teacher is very effective in actively checking on progress and providing additional challenge.

Key features

- very good classroom management
- very good planning for practical procedures
- exemplary exposition and very clear instructions
- clear focus on working scientifically
- students involved in predictions and concerned with accuracy
- very high levels of application and good collaboration
- students very willing to answer and ask questions
- very good links to prior learning and concern for scientific literacy.

96. Secondary example 2: Year 10

Throughout this session, levels of application and engagement are high. The students are sorting photo cards into sets representing selective breeding and natural selection. Discussion in groups about the task and the decisions being made is very good. The teacher is very effective in challenging ideas and promoting further thought through targeted questioning and intervention. The additional challenges are made seamlessly; they 'stretch' students effectively. The groups then carry out one of two research tasks, using ICT and printed sources, on natural selection and how this accounts for adaptation and speciation.

Groups are engaged in self-evaluation and explain their successes in learning to the others. The plenary session is managed very effectively so that the learning within the groups becomes available to the whole class.

Key features

- very high levels of application

- questioning was very effective at checking understanding and promoting the students' engagement through their answers
- very good pace with no slack time; high levels of demand and high expectations
- excellent planning and sequencing of activities, supported by very good resources
- a clear framework displayed for pupils' self- and peer evaluation; using the framework was an integral part of the task
- very clear feedback requirements for peer evaluation, which were adhered to.

97. Secondary example 3: Year 10

The session begins with the teacher's lively presentation of the task. His well-targeted questions check the students' understanding skilfully and he uses some of their light-hearted responses effectively to motivate them and clarify the task. All the students are engaged.

The revision of ecology as part of the preparation for the International Baccalaureate in biology becomes an enjoyable task that promotes high levels of application and activity. The research-based activities are managed well and the pace of learning is good. Good reflective practice is used to bounce back students' ideas to them for further refining.

The students, including those who are learning English as an additional language, are challenged to use appropriate language. They present their findings in a range of ways. One student's research presentation on Charles Darwin is of high quality, accurate, and reported with obvious understanding. When he is challenged by fellow students, his explanations are lucid. The students are clearly used to debate and discussion. They pose questions well and respect the views of others. The atmosphere is one of fair debate. The teacher's close monitoring is effective throughout the lesson and provides additional challenge. The plenary session involves the students in using ICT to test their own understanding.

Key features

- very inclusive lesson; all were encouraged and kept engaged
- teacher vigilant in monitoring progress
- very good management of the lesson, with positive encouragement rather than negative interventions
- very well-structured lesson with excellent resources and use of ICT
- students understand the work and show good skills of independent learning
- teaching was very responsive and focused on the learning needs of individuals.

98. Secondary example 4: Year 13

The teacher gives a very clear explanation of particle vector motion which is illustrated well using ICT. The students are engaged by effective question and answer techniques in preparation for tackling A-level questions.

The work is challenging. The teacher gives the students excellent advice about how they might set about answering the questions by outlining a response using their ideas. The following session includes a good balance of individual, paired and whole-class work with all the students contributing to an effective response to the set question. The teacher uses the interactive whiteboard very well to capture the different ideas and responses.

The teacher is very effective at monitoring students' progress and demonstrates his very secure subject knowledge. His responses to the students' questions are effective and, in turn, these provide additional challenge. Students begin to spot anomalies in the responses of others and in the data presented. They are well-tuned to the requirements of the questions and correctly understand what they need to do to maximise their marks. Relationships between the teacher and students are very positive and humour is used on both sides to good effect.

Key features

- high levels of application and involvement of students in the lesson
- explanations were clear and well-understood
- students responded well in answering questions and, in turn, raised their own questions
- a good range of activities allowed for individual, paired and group work; whole-class activities consolidated students' understanding
- students had excellent attitudes to work
- the teacher was very skilled at asking questions for a range of purposes
- the teacher was vigilant in monitoring progress.

From satisfactory to good and beyond

99. The following examples are descriptions of satisfactory science lessons. Suggestions are made about how the lesson might be improved to raise the quality to at least good.

100. Primary example 1: Reception Class

The teacher begins to outline the activities for the morning. During their time sitting on the carpet, the children are restless and their attention is only satisfactory. The range of activities is quite prescribed and there is little evidence of the teacher using suggestions the children make. There are two teaching assistants who do little to encourage the children's engagement with what the teacher is explaining.

The class splits into different activity groups: work on floating and sinking, use of computer programs, and water play, filling plastic bottles and plastic containers of different shapes and sizes. The experiences are well-planned but not carried out fully in practice. The teaching assistants are not taking a full part in the learning activities but tend to child-mind and concentrate on mopping up water spills and so on. The children are active and engaged for much of the time. In the main, they are focused on the tasks they have been set. They are learning but the pace is only moderate. There is some good development of language because the teacher interacts with the children during their activities. There is no plenary work by the teacher in the groups, so the learning is not shared as well as it might be.

Areas for improvement

- The session needed more structured interaction between the adults and children. The children naturally enjoyed the exploration activity but the interaction with adults to talk about what was happening and to encourage more focused observations was limited.
- The teaching assistants should have been better briefed, so that they had a clear understanding of their role in promoting learning and were able to raise the quality of the learning by more effective intervention. Their limited contribution was the weakest feature of the session.
- Developing the children's language should have been a priority for all the adults in the class. This was proceeding well for the children who had the teacher's attention but the teaching assistants were under-deployed in this area and did not engage children as much as they could have done.
- The children's ideas and suggestions could have been better exploited. Opportunities to evaluate and build on their ideas could have had a positive impact on promoting their engagement and guiding learning.

101. Primary example 2: Year 2

At the start of the lesson, many pupils respond to the teacher's question and answer session but not all pay good attention. Vocabulary such as 'photosynthesis' arises but there is no overt checking of understanding by the teacher. Clearly, some pupils have used the word and associate it with plants making food from sunshine. For some their understanding is not secure and this is not recognised or challenged by the teacher. During the questions and answers, the teacher describes the roots 'taking up food'. This is inaccurate and can lead to misconceptions, as it is water and minerals/nutrients that are taken from the soil by the roots. Pupils' attitudes are good and most are keen to answer the teacher's questions.

The notion of fair testing is understood by many and their responses to questions, expressed in their own language, indicate good understanding.

There is an ICT display of seasonal pictures with different forms and stages of life, which provides a rolling presentation of living things and growth.

The class is organised into groups efficiently and the teacher uses ICT effectively to set out procedures and instructions for the work to be done. She elicits their ideas well but does not respond effectively to a couple of the more inventive ideas that she was not expecting. The pupils set up apparatus to investigate water absorption, but the equipment provided is not well-matched to the activity; for example, one-litre jugs are used for measuring 100ml. Spillages and inaccuracies are not challenged and nor are the pupils spotting the problem that this poses. The teacher’s main concern seems to be to complete the activity, and there is insufficient focus on the quality of the practical work and the refining of the pupils’ thinking. They enjoy the work and behave responsibly, even if the accuracy and the pace of learning are only satisfactory.

Areas for improvement

- The lesson would have been more effective if the teacher had had a clearer understanding of what the pupils already knew or did not know about plants and the way that they make food. Assessment for learning techniques could have informed her of areas of misunderstanding, as could initial discussions between pupils, working in pairs or small groups.
- Although it is challenging to do so, the teacher needed to ensure that she used scientific terms accurately. Consulting the science coordinator before each unit of work to check the key vocabulary and its meaning is an effective way of doing this. Some schemes of work have key words highlighted to alert teachers to their accurate use. The problems in science can often involve words where the common meaning is different from the more precise scientific usage.
- The practical equipment used should have been appropriate to the task, allowing pupils to make sufficiently accurate measurements. The teacher herself clearly did not have an adequate understanding of the need for accuracy.

102. Primary example 3: Year 4/5

The pupils are working on planning an investigation of materials suitable for making a model ship. The work is set within a theme involving Tudor ships. The teacher leads a class discussion on fair testing, changing variables and measuring. This goes on for too long and pupils begin to lose interest.

The class is split into groups depending on their attainment. The different groups have different questions to tackle related to the strength, flexibility and floating properties of the materials. The pupils are using a standard planning sheet to provide focus and minimise the language required to plan their work. When the pupils move on to their own planning, many find it difficult, particularly in setting up a fair test.

The materials provided include a cardboard cereal box, a foil tray, a length of wood, cardboard tubes, felt and other materials. All these are of different sizes and shapes and no means is provided of cutting the materials to the same shape and size. Some pupils are puzzled by this and teacher passes over the questions they ask about it. The teaching assistant does some very good work with a group of low-attaining pupils by asking pertinent questions and giving clear guidance to move their ideas along. The teacher circulates around the groups, checking on their progress but a few groups struggle to come up with a plan for an investigation they can undertake. The teacher's lack of direction does not help the pupils to make suitable progress and it allows some less-committed pupils to wander off-task.

Areas for improvement

- The lesson illustrated the challenge of combining science and design and technology. A lack of understanding of this combination led to inappropriate materials and equipment being deployed in a task that frustrated pupils. The science learning objectives needed to be clearer.
- A better approach to the notion of fair testing would have been to start with a well-structured class discussion in order to pick off issues one by one, to develop a common understanding of the challenge and identify a number of strategies to tackle the problem. The provision of different questions to different groups, with the assumption that a fair test could be applied to them all, showed a misunderstanding of the subject's demands.
- Although the teaching assistant's contribution to the pupils she worked with was good, this was on her own initiative. The whole class could have benefited from support being better allocated across the different groups.
- The pupils needed more judicious use of instruction and direction when they were unclear about how to proceed. This would have helped their confidence and made it possible for them to work more constructively. The teacher's withholding of direction and her lack of response to questions were not effective in getting pupils to think.

103. Primary example 4: Year 6

The theme of the lesson is the rate at which a solid dissolves. The teacher asks the pupils to put their ideas about the variables involved on sticky notes and to place them on laminated cards, in groups, to see how many and what types of variables are identified. Some confusion begins as the pupils start work. Out of the six groups, two have not understood the challenge and are reinforcing misunderstanding through their discussions with one another. Teaching assistants had watched the initial 'start up' but do not challenge the misunderstandings sufficiently and it is some time before the teacher gets round to all six groups.

The pupils are well-motivated and keen to take on the task. They have satisfactory practical skills. There is confusion among some of them as to what they are to measure; some are measuring the independent variable rather than the dependent variable. The idea behind the practical work is sound and simple, but the execution is weaker than it could be because the teacher and teaching assistants are not tuning pupils into the work with sufficient clarity, and intervention is limited by the inefficient deployment of the teaching assistants.

While learning is progressing satisfactorily, the rate could be quicker. The phrasing of the questions to investigate is difficult for some pupils and the teaching assistants become more active in helping pupils to clarify their ideas and language as the lesson proceeds. The teacher refers to dissolving, inaccurately, as a change of state. Some pupils decide to measure how much sugar is added to the water by measuring the volume of sugar. The teacher uses 'volume' in talking to these pupils while with others she refers correctly to the 'mass' of sugar, and pupils set about measuring the sugar by using electronic scales. Some pupils do not understand what the difference is between mass and volume and this also leads to some confusion.

Areas for improvement

- The teacher could have taken more time to clarify the pupils' thinking about and understanding of the task before they started on it.
- A whole-class session of question and answer would have clarified pupils' prior knowledge and understanding. This would have helped the teacher to determine how well individuals understood. She could then have worked with the weaker pupils to promote their understanding while encouraging the higher attainers to 'get on with it'.
- The teaching assistants should have been briefed more clearly about the lesson's learning priorities. They were under-deployed initially, although they eventually focused appropriately on groups and individuals who were struggling with organising language, ideas and equipment.
- The teacher's inaccurate use of some scientific vocabulary could have been a stumbling block to effective learning. Whenever practicable, teachers should check their own understanding, for example with the science coordinator.

104. Secondary example 1: Year 7

The inspector observes the second half of a lesson, in which the students are engaged well in making ‘fruit batteries’.

They have been following satisfactory printed instructions, but some students start on the activity without sufficient reference to the written instructions and so waste time. The teacher has to call repeatedly for attention, and partially succeeds, but some students continue their practical work quietly and do not pay attention to what she says.

The teacher is active in circulating around the class and checking progress, and she makes some effective interventions with individual students, most often the more voluble ones. Quiet students do not attract her attention sufficiently. Overall, the students’ application is good. Their practical skills are satisfactory and they are clearly enjoying the practical work. However, the process of measuring current does not get as far as repeating measurements for reliability. The teacher manages behaviour by chivvying individuals rather than creating a more purposeful environment for learning. These interventions are effective for a limited time only and then need repeating.

The plenary session is aimed at finding which fruit produced the highest reading on the voltmeters. However, some students refer to ‘current’. Their contributions are not challenged, with the result that ‘voltage’ and ‘current’ become interchangeable in the class’s vocabulary. The question and answer session is not well-targeted, so some students have a quiet time compared with the majority who readily offer answers to the teacher’s questions. The final part of the plenary is a well-run session on evaluating the experiment and making improvements; this involves more students and engages them better. The activity and involvement of the teaching assistant in the room are minimal. She has the lesson plan but clearly had not engaged with it or with the teacher. Overall, the pace and challenge are only satisfactory.

Areas for improvement

- There needed to be clearer ‘rules of engagement’ for behaviour. The teacher tolerated students talking while she was talking; even when this was fairly quiet, it was symptomatic of their inattention.
- The teacher repeatedly made announcements while the pupils worked. She should have said all that she needed to say with the students’ full attention and then let them get on while she modified their thinking and activity by intervening with groups or individuals.
- Questioning needed to be better targeted to challenge the knowledge and understanding of all students. This should avoid individuals being allowed to sit quietly and not to be required to answer a question.

- Careless use of specialist language should have been challenged, and accurate use of vocabulary established as critical for future progress.
- The teaching assistant should have been more gainfully employed. Although the teacher had given her a copy of the lesson plan, there had been no discussion to tune her into the lesson. The assistant could have been useful in checking on students' understanding of what they were doing and could have offered some challenge on matters such as the accuracy of their measurements and recording.

105. Secondary example 2: Year 9

The teacher explains the aims of the lesson in general terms and refers to the pupils' earlier knowledge and experience from Year 7. However, the lesson plan underestimates the time needed for an effective starter activity. The teacher's amusing example of a clockwork frog illustrates energy transfers, and the questions and answers are effective during the demonstration to engage the students.

When the teacher gets on to the main topic, the teaching is enthusiastic but slightly unfocused at times, allowing the students' concentration to drift. He draws some simple electrical circuits on the interactive whiteboard and involves the students in including voltmeters and ammeters into the circuits. The emphasis on the differences between series and parallel circuits is good.

The teacher organises the class into small groups but they have to wait to collect equipment in turn. This gives much scope for off-task chat. The teacher's instructions to draw a circuit, build it and record meter readings are rambling and unfocused. The instructions therefore need to be repeated and time is lost. A few students ignore the supplementary instructions and continue to fiddle with the equipment. A few spend an inordinate amount of time drawing their circuit diagrams. They do not generally carry out the measurements in parallel and series circuits as planned. Although the students enjoy the lesson and make a variety of circuits, the learning is only satisfactory.

Areas for improvement

- The teacher needed to be more focused on the expected learning, as a means of keeping students on track. More thorough use of targeted questions during the start-up session would have made it more likely that the students knew what was wanted in procedural terms. This clarity would have led to stronger conceptual development.
- The distribution of equipment needed to be more efficient. The groups waiting to be called quickly lost concentration. A number of collection points for equipment would have make a rapid start more likely, as would the better organisation of tasks within the groups.

- Greater priority needed to be given to teaching students how to work together more effectively in small groups.
- The teacher needed to monitor the work of the groups more closely to ensure that they remained fully on task and met the learning objectives.

106. Secondary example 3: Year 10

The students have an introductory word search to settle them down. The teacher does not make connections between the word search and the main objectives of the lesson which are concerned with food additives.

The teacher directs students into groups without engaging them through questioning or discussion of the topic. Each group is given different information and is told to use not more than 15 words and drawings to communicate the information to other groups. Groups get straight into the activity, but not all read of them the briefing material thoroughly. They work on flipchart paper but the hexagonal connected benches in the room make it difficult for the whole group to see what is going on. In most of the groups, one student does the reading and suggests ideas while the others occupy themselves in drawing the pictures and colouring in letters, or just sit and watch. The learning is not rapid, although some students are clearly acquiring vocabulary and knowledge.

The teacher moves around the groups, stressing the time and the constraints of the word count. The teaching assistant does some constructive work with two groups by giving clues as to the direction to take. The final flip charts are thin on detail and have an elementary treatment of the issue of additives in food. Conversations between students show that not all have understood terms such as ‘emulsifier’ or ‘antioxidant’.

Areas for improvement

- A more purposeful starter activity could have been used by the teacher to find out what students already knew about food additives.
- Since the students were intended to learn by reading from the source material, the classroom activity needed to ensure that all of them did so. As only a few students read the materials, the work began with many students not understanding the vocabulary and not having a clear view of their role.
- The group work needed to be much better structured to achieve the planned learning objectives. Group work is not simply a matter of seating students in groups and letting them get on with a task. Effective group work should make sure all the students are involved and have clear roles for which they are accountable. The way that this class was organised meant that significant ‘spectator activity’ was allowed rather than active involvement.

- The teacher's monitoring of progress should have focused on students' understanding rather than on superficial factors.

107. Secondary example 4: Year 12

The teacher initiates a discussion with students about pigments in leaves, the changes that are observed with time and what might account for the changes. There is no visual stimulus but simply recollections of experiences. Not all students seem to have such recollections, as their lack of contributions makes clear. The teacher's questions are not directed towards particular students. Half the class seems very keen to answer questions and discuss ideas but the other half is not drawn in. The exchanges with the teacher are loosely organised, resulting in more than one participant talking at once.

Descriptions of the following practical work are given and read, but not discussed. Students carry out the practical work appropriately, but with some gaps in their knowledge of details, such as different rates of translocation in chromatography, which they covered in Key Stage 4. These are not discussed again with the teacher at this setting-up stage of the lesson. The teacher had not established the consideration of accurate measurement sufficiently well to challenge students in the way that they carried out the procedures. Some students raise some good questions; these are answered rather superficially and then set aside.

The atmosphere in the class is friendly but, at the same time, unchallenging, particularly for the most academically able. By the end of the lesson, learning had taken place but not at a pace or depth that could be regarded as more than satisfactory.

Areas for improvement

- The teacher's questioning needed to be more purposeful and better focused. Well-structured and directed questions at the start of the lesson could have ensured that all students understood the challenge well and any areas of uncertainty could have been cleared up.
- Questioning could also have established what the students already knew. Some of the teacher's assumptions about what the students knew or could recall from their work in Key Stage 4 were inaccurate.
- Students' questions should have been answered properly and exploited to provoke deeper thinking, rather than being left and lost by the end of the lesson.
- The lesson needed a better-structured start to enable the students to get into the practical work more quickly and effectively, and with the required accuracy and attention to detail that set A-level work apart from that at Key Stage 4.

Getting on the right path

108. As described earlier in the report, there have been significant changes to the curriculum in secondary schools since September 2006. The increased range of courses and the freedom to vary the length of Key Stage 3 and GCSE courses have made it more possible to match the courses to the needs of students. The increased number of courses makes the choice of courses key to securing pathways through and beyond secondary school. Choices made at the end of Key Stage 3 should be informed not only by what the courses in Key Stage 4 will entail but what they can lead to beyond the age of 16.

109. In February 2010, Ofsted carried out a short survey to look at what students were choosing in response to the increased curriculum choice available since the new GCSE science courses were introduced in September 2006.[13] The survey provided evidence of the extent to which advice, information and guidance were secure in the secondary schools visited in keeping options open for students' future education, training and careers.

110. The majority of the Key Stage 4 students spoken to during the survey were content with the science courses that they were following. Only 5% of the students who completed an electronic questionnaire were unhappy with their courses.[14] Inspectors judged that the schools were directing the vast majority of students appropriately to suitable courses at the end of Key Stage 3. Very few students felt misdirected.

111. The match of students to courses was commonly based on analysis of performance data, teachers' views of students' likely success with test-based or coursework-based examinations, and students' previous effort in and commitment to learning. Where students were allocated to vocational pathways, it was most often because the qualification was awarded through coursework only; the teachers believed that the students would achieve higher grades as a result of this method of assessment.

112. All the schools visited as part of the February 2010 survey provided information to students and their parents and carers about science courses. Half of the schools had considered the readability of the information and made suitable adjustments, but others had used verbatim text from examination board information; for example in relation to examination formats and different kinds of assessment strategies.

113. Most of the Key Stage 4 students interviewed did not know enough about their attainment, their areas of weakness and how they might improve. They were, therefore, less well-placed to take some responsibility for their progress through

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[13] *Guidance for students studying science* (100045), Ofsted 2010; www.ofsted.gov.uk/publications/100045.

[14] A total of 1,623 Key Stage 4 students returned questionnaires which were recorded electronically and analysed in detail for the survey.

their science course. The questionnaire showed that 22% of the students had been given information about careers that they could enter with science qualifications. Staff were aware of the limitations and career implications of following particular courses, but this awareness did not necessarily find its way into the advice offered. Essentially, the information and advice were of little use since most of the students did not actively express a preference between courses nor did they want to.

114. The Year 12 students interviewed were better informed and their choices for post-16 courses were managed more rigorously, and with better support, than those for students at the end of Key Stage 3 who were choosing 14–16 options. A large majority of the 195 sixth form students spoken to in the schools visited had a good understanding about science courses and the connection to further careers. The sixth form survey also suggested that almost every student was content with her or his choice of science studies.

115. In the schools visited that had sixth forms, the uptake of post-16 separate science level 3 courses was not limited by whether the students had studied double award GCSE or triple science but by whether they had reached a minimum threshold grade for entry to the post-16 course. The sixth form students chose science mainly because of their interest in and enjoyment of it; they often cited good teaching as a factor that attracted them to it. For the majority of these students, a science qualification was also necessary for their particular career intentions. But, significantly, the ambition to follow a science career came from enjoying the study of science at Key Stage 4.

116. Students who had followed a vocational course at Key Stage 4 had limited opportunities for studying vocational science at either level 2 or level 3 at post-16 level, and were ill-prepared for separate sciences at AS and A level. Students who had studied applied science at GCSE could progress to applied science A level, but were not easily able to pick up a separate A-level science. This limitation was not the case for students who studied double award or triple science at Key Stage 4: they could choose vocational or applied level 3 science courses as well as the separate science AS/A levels.

117. Most of the students spoken to in Key Stage 4 and in the sixth form said that practical investigative work was the aspect of science that they enjoyed most. They also described a healthy mix of academic challenge, independent research, group work and discussion of difficult and topical scientific concepts as promoting their interest and enjoyment. Students spoken to in the sixth form who had chosen not to follow science courses at AS and A level had done so because they found other subject areas more personally interesting, and only occasionally because they had not enjoyed the style of teaching they had experienced in science at Key Stage 4.

Supporting science in the primary school

118. A number of issues relating to science in primary schools have been described in this report and are reflected particularly in the lower levels of outstanding provision in these schools compared to the secondary schools visited:

- the lack of confidence of some primary teachers in teaching science
- the low take-up of science-specific continuing professional development
- the reduced levels of support provided by local authorities.

These factors have contributed to a lack of overall improvement since the last report on standards, as measured by teacher assessment data in Key Stages 1 and 2.

119. However, inspectors found examples of some primary schools making improvements. These schools had focused on analysing and developing their science practice and, consequently, had improved pupils' engagement, enjoyment and achievement, as in this example.

> In aiming to achieve the Primary Science Quality Mark, the teachers were determined to inspire and motivate pupils in science.[15] They decided that the opportunities provided should be relevant and exciting. By conducting initial interviews with a sample of pupils, the teachers identified a number of opportunities to improve science teaching. The profile of the subject was raised through:
>
> - the training of all members of staff
> - the introduction of a whole-school science week
> - a significant increase in the number of science-related trips and visiting speakers.
>
> Inspectors' discussions with school council members across the age range showed that the aims had been met. Key improvements identified by the pupils, teachers, governors and parents were:
>
> - an increase in practical science
> - more visits, visitors and links with outside organisations
> - more opportunities for pupils to experience science outside lessons
> - increased understanding of teaching and learning of science
> - governors' and parents' greater awareness of science in the school
> - the development of the role of the science manager.

120. Inspectors identified some important mechanisms for bringing about improvement in primary science. One of these was the Primary Science Quality Mark. This aims to raise the profile of science in primary schools, provide an

[15] Further details of the Primary Science Quality Mark are given in the Notes.

effective framework for developing and evaluating science teaching and learning in primary schools, and promote a commitment to excellence in primary science. Inspectors' interviews with staff in the schools that participated in the initiative confirmed the improvements in teachers' confidence and ability to teach science, with a consequent positive impact not only on pupils' performance but also on their engagement and enjoyment.

121. The initiative has shown how strongly motivated professionals in science education can work with science-based industry and other agencies to promote higher standards in science education.

Quality in continuing professional development

122. In 2010 Ofsted published *Good professional development in schools.*[16] The key strengths and areas for development which inspectors identified in science inspections closely reflected those in this wider-ranging survey. The strengths included:

- the strong commitment of senior managers to developing their staff
- the close alignment of professional development with performance management, institutional self-review and priorities for improvement
- the flexible use of time, resources and expertise
- the successful balancing of individual and institutional needs.

123. A further strength identified in this report was the focus by the institutions on developing not only the teaching staff but also the wider workforce. Inspectors found several examples of staff who had been given the financial support and time to gain extra qualifications that considerably extended their career capabilities. Investment in professional development had a very positive impact on recruiting and retaining staff.

124. Despite these strengths, inspectors identified three barriers to improvement. First, there were continuing weaknesses in the evaluation and assessment of the value for money of professional development. Second, teachers' knowledge of subjects other than English and mathematics was seldom refreshed by suitable professional development, especially in primary schools. Finally, schools in which staff, particularly leaders, lacked skills in self-evaluation and in dealing with weaknesses needed help before professional development needs could be met.

125. The report identifies four key questions that leaders need to ask themselves if they are to be successful in planning professional development. These relate to:

[16] *Good professional development in schools* (080254), Ofsted, 2010; www.ofsted.gov.uk/publications/080254.

- the extent to which professional development is integrated with school improvement
- how well the school provides policies and frameworks to secure consistency and quality in the work of staff
- the extent to which the expertise of staff is used
- how well the school monitors and evaluates its professional development.

126. The important contribution of continuing professional development (CPD) to raising standards in science is described elsewhere in this report. The predominance of generic CPD and the paucity of science-specific CPD, particularly in primary schools, are also noted. The importance of high-quality CPD for science was recognised by the introduction of the network of Science Learning Centres. Since 2004, in collaboration with the Wellcome Trust, the former Department for Children, Schools and Families had established a network of Science Learning Centres to provide high-quality professional development for all those involved in science education in primary and secondary schools and further education.

127. There are nine regional centres in England and a national centre at the University of York to serve all the United Kingdom. Their mission is broad, embracing psychology, earth science, astronomy, citizenship and other areas, in addition to the three traditional sciences. The intention is to improve subject knowledge, encourage inspirational and innovative teaching, and bring contemporary science into the classroom. Reflecting this mission, all the centres have close links to higher education institutions and have a wide range of partners from industry and the professions, as well as schools and local authorities.

128. During the period covered by this report, inspectors visited almost all the Science Learning Centres, held interviews with course members and were present at evaluation sessions with course members. The teachers indicated that they were benefiting from the experiences and had very positive views about the courses they were following. The impact of CPD at one Science Learning Centre is illustrated below.

> During the second session of a course in leading science in challenging circumstances, the head of science from an average-sized secondary school gave an account of the impact of training he had received. He was in his late forties and described how he had been ‘stuck in a rut’ when his headteacher ‘sent him’ on the course. After his initial resentment and lack of warmth towards the course, he was influenced by the quality of presentations and the vigour of fellow course members. The structure of the course required members to carry out some development work in their own schools before attending the second session later in the year. He had worked on improving the assessment and tracking system in science and making clear links between data gathered and planning for individuals. He

described how morale had lifted among science teachers and how the outcomes for students had improved.

129. Further examples of evaluations of other training courses run at Science Learning Centres highlight their influence on teaching, learning and the curriculum:

On a physics course: 'I found that updating my skills was very rewarding as it helped to motivate my students. I enjoyed learning about these techniques and thinking how to incorporate them into my lessons. There has also been a spin-off benefit to my colleagues. Some students made comments about how they had enjoyed the lessons more since I started to incorporate more collaborative tasks, and I hope to see an improvement in their grades in the summer. I will continue developing my use of the materials covered on the course. Also, I wish to arrange some INSET opportunities for colleagues who would like some help with teaching the physics topics at Key Stage 3. Influenced by the research we studied, I want to analyse the take-up of triple science in our school to check that no features of the teaching or school curriculum are dissuading girls from following this route.'

On a science management course: 'I decided to attend "New and Aspiring Heads of Science" because I wanted to be able to fully support and challenge all the members of my department, including technicians and teaching and learning assistants, through effective leadership, target-setting, monitoring, reflection and evaluation of practice. I also wanted to make a positive impact on the everyday teaching and learning experiences of students during their study of science.

'The course material was provided using inspirational teaching and learning methodologies, modelling good practice, role-plays, lab sessions, and action-planning. Research and development tasks carried out back in school were assessed for their impact.

'I particularly enjoyed the sessions on "creating a science team rather than a science department", "creating and communicating a shared vision", "from good to outstanding" and "coaching". Every session was packed full of great, useful ideas to be brought back to the classroom and, because of this, the course has had a significant impact on how science is delivered and managed in my school.

We made changes to teaching methods used by all teachers in the department by providing INSET to give teachers opportunities to experiment with "new" pedagogy. Schemes now make "skills teaching" more explicit. Students love the active teaching and learning methodologies brought back from the course.

‘I’ve put many aspects of the course into practice. I’ve learnt how to run effective meetings, how to be assertive, how to be creative with my budget, and many more skills.’

130. The proportion of secondary schools visited that had used the services of Science Learning Centres, however, was relatively low, although most of these schools were aware of the Centres’ existence and purpose. Some were aware of the courses offered but did not apply for them because of perceived financial constraints and the distance from their nearest centre. A large majority of the primary schools visited were not aware of the courses and services. They were also unclear about what other sources of professional development were available. Secondary schools had a better understanding of the training opportunities that the centres offered, and all of those who had used them had found the support helpful.

Notes

This report is based on evidence gathered during the period June 2007 to March 2010. Through the subject survey programme for science, Her Majesty’s Inspectors (HMI) and additional inspectors visited a sample of 94 primary, 94 secondary and two special schools across England. No school that was in one of Ofsted’s categories of concern (that is, having a notice to improve or requiring special measures) was included in the sample of schools visited. The survey has also drawn on inspections of post-16 science education in colleges.

The report was also informed by evidence gathered through conferences and meetings with organisations such as the Qualifications and Curriculum Development Agency, the Secondary National Strategy, Science Learning Centres, and the National Advisers and Inspectors Group for Science. In addition to these, HMI gathered information and views from a range of organisations concerned with science education. These included: the Association for Science Education; the Royal Society; the Royal Society of Chemistry; the Institute of Physics; the Society of Biology; Science Community Partnership Supporting Education; the Earth Science Teachers’ Association; and the Consortium of Local Education Authorities for the Provision of Science Services.

Some of the schools visited by inspectors were part of the pilot phase of the Primary Science Quality Mark, funded by The Wellcome Trust. The pilot phase in 2008 (12 schools in the East of England) involved other partner organisations contributing in kind: Science Learning Centres; the Association for Science Education; and Barnet local authority. The second phase of the scheme, involving 49 schools, began in 2009. The target is for 1,800 schools to achieve the Primary Science Quality Mark award between 2010 and 2013, rising to over 30% of all United Kingdom schools by 2018.

Ofsted

Further information

Publications by Ofsted

Guidance for students studying science (100045), Ofsted, 2010; www.ofsted.gov.uk/publications/100045.

Subject-specific guidance for inspectors on making judgements during subject survey visits to schools, Ofsted, 2010; www.ofsted.gov.uk/publications/20100015.

Success in science (070195), Ofsted, 2008; www.ofsted.gov.uk/publications/070195.

Other publications

Science and innovation investment framework 2004–2014: next steps (06/1245), HM Treasury, 2006; http://bis.ecgroup.net/Search.aspx.

In 2004, the then Department for Education and Skills collaborated with Her Majesty's Treasury, the Department of Health, and the Department of Trade and Industry to produce a discussion paper about the position of science in education and the economy. It presents the next steps in five key policy areas: maximising the impact of public investment in science on the economy through increasing innovation; increasing research councils' effectiveness; supporting excellence in university research; supporting world-class health research; and increasing the supply of science, technology, engineering and mathematics (STEM) skills.

Websites

Association for Science Education (ASE)

This is the UK's largest science association dedicated to the teaching of science.
www.ase.org.uk

Consortium of Local Education Authorities for the Provision of Science Services (CLEAPSS)

CLEAPSS is an advisory service providing support in science and technology for a consortium of local authorities and their schools, including establishments for pupils with special needs. Independent schools, post-16 colleges, teacher training establishments, curriculum developers and others can apply for associate membership.
www.cleapss.org.uk

Earth Science Teachers' Association (ESTA)

The aim of the ESTA is to advance education by encouraging and supporting the teaching of earth sciences at all levels, whether as a single subject such as geology, or as part of science or geography or other courses.
www.esta-uk.net

Institute of Physics (IoP)

The Institute of Physics runs a web-based resource for schools and colleges. It provides information about its latest curriculum development initiatives, the Affiliated Schools Scheme and professional development courses, as well as links to and information about various support networks.
www.iop.org/activity/education/index.html

National Advisers and Inspectors Group for Science (NAIGS)

NAIGS is the subject group for science inspectors, advisers and consultants. It is affiliated to and administered by the Association for Science Education. Its role is to provide continuing updating of information and developments in science, professional development and networking opportunities. It has close links with schools in all phases to support and advise staff on science education.
www.ase.org.uk/professional-development/naigs

Royal Society

The Royal Society is the national academy of science of the UK and the Commonwealth and is at the cutting edge of scientific progress. The teachers' section of the website can be found at:
http://royalsociety.org/

Royal Society of Chemistry

The education activities of the Royal Society of Chemistry cater for chemical scientists of all ages. The organisation produces resources for teachers, lecturers and students, provides training and continuing professional development, maintains professional registers and contributes to education policy.
http://rsc.org/

Science Learning Centres

Science Learning Centres are a national network for professional development in science teaching. Their aim is to improve the teaching of science and to inspire pupils. There are nine regional centres in England and one national centre, each with a number of satellite centres. The national centre aims to reach all the secondary schools in the UK.
www.sciencelearningcentres.org.uk

Ofsted

SCORE: Science Community Partnership Supporting Education

SCORE is a partnership of six organisations: the Association for Science Education, the Institute of Physics, the Royal Society, the Royal Society of Chemistry, the Science Council and the Society of Biology.
www.score-education.org

Society of Biology

The Society of Biology is a single unified voice for biology: advising Government and influencing policy; advancing education and professional development; supporting its members, and engaging and encouraging the public's interest in life sciences.
www.societyofbiology.org

The Learning and Skills Improvement Service

The Learning and Skills Improvement Service is responsible for building capacity in the learning and skills sector to design, commission and deliver programmes which support the improvement of quality and strategic change.
www.lsis.org.uk

Annex A. Providers visited

Primary schools	Local authority
Ambleside Primary School	Cumbria
Appleton Roebuck Primary School	North Yorkshire
Archbishop of York's CofE Voluntary Controlled Junior School, Bishopthorpe	York
Badgerbrook Primary School	Leicestershire
Becontree Primary School	Barking and Dagenham
Beeston Rylands Junior School	Nottinghamshire
Benhurst Primary School	Havering
Bishopthorpe Infant School	York
Blacklands Primary School	East Sussex
Blue Bell Hill Primary and Nursery School	Nottingham
Bow Community Primary School	Devon
Broughton Jewish Cassel Fox Primary School	Salford
Catcliffe Primary School and the Meadows Children's Centre	Rotherham
Caton Community Primary School	Lancashire
Cherry Lane Primary School	Hillingdon
Conisbrough Station Road Primary School	Doncaster
Cuddington Community Primary	Surrey
Diocesan and Payne Smith Church of England Primary School	Kent
Downsbrook Middle School	West Sussex
Drayton Park Primary School	Islington
Edleston Primary	Cheshire East
Eton Park Junior School	Staffordshire
Flockton Church of England Voluntary Controlled First School	Kirklees
Fordcombe Church of England Primary School	Kent
Funtington Primary School	West Sussex

Gilthill Primary School	Nottinghamshire
Glade Primary	Redbridge
Granby Junior School	Derbyshire
Greengates Community Primary School	Knowsley
Harlesden Primary School	Brent
Harlyn Primary School	Hillingdon
Hawksworth Wood Primary School	Leeds
Hillview Primary School	Halton
Holy Cross Catholic Primary School	St Helens
Holy Family Catholic Primary School	Knowsley
Honeywell Junior School	Wandsworth
Kettlefields Primary School	Cambridgeshire
Kirby Hill Church of England Primary School	North Yorkshire
Laleham CofE VA Primary School	Surrey
Leck St Peter's Church of England Primary School	Lancashire
Limehurst Community Primary School	Oldham
Linden Road Primary School and Hearing Impaired Resource Base	Tameside
Lionwood Junior School	Norfolk
Little Gaddesden Church of England Voluntary Aided Primary School	Hertfordshire
Markington Church of England Primary School	North Yorkshire
Meridian Primary School	Greenwich
Murton Community Primary School	Durham
Mytham Primary School	Bolton
New Penshaw Primary School	Sunderland
Old Fletton Primary School	Peterborough
Old Priory Junior School	Plymouth
Oldbury on Severn Church of England Primary School	South Gloucestershire
Paxton Primary School	Lambeth

Pevensey and Westham CofE Primary School	East Sussex
Preston Park Primary School	Brent
Redlands Primary School	Reading
Richard de Clare Community Primary School	Essex
Rokesly Junior School	Haringey
Rolleston Primary School	Leicester
Rose Hill Primary School	Stockport
Roseberry Community Primary School	North Yorkshire
Ruislip Gardens Primary School	Hillingdon
Rushey Green Primary School	Lewisham
Sandhill Primary School	Barnsley
Sidegate Primary School	Suffolk
Spelthorne Junior School	Surrey
Springmead Primary School	Hertfordshire
Springwell Junior School	Hounslow
St Anne's (Stanley) Junior Mixed and Infant School	Liverpool
St Anne's and St Joseph's Roman Catholic Primary School, Accrington	Lancashire
St Cuthbert's Roman Catholic Voluntary Aided Primary School, New Seaham	Durham
St Dominic Catholic Primary School	Hertfordshire
St George's Church of England Primary School	Stockport
St Hugh's CofE Primary School	Oldham
St Nicolas CofE Junior School	West Berkshire
St Paul's Primary School	Wiltshire
St Peter's Catholic Primary School	Birmingham
St Thomas More Catholic Primary School	Birmingham
Stanton Road Primary School	Wirral
Stretham Community Primary School	Cambridgeshire
Taxal and Fernilee CofE Primary School	Derbyshire

The Billinghay Church of England Primary School	Lincolnshire
Throston Primary School	Hartlepool
Town Farm Primary School	Surrey
Trowell CofE Primary School	Nottinghamshire
Upland Primary School	Bexley
Wellfield Methodist and Anglican Church School	Lancashire
Wembrook Primary School	Warwickshire
West Twyford Primary School	Ealing
Westbury-On-Trym CofE Primary School	City of Bristol
Wheldrake with Thorganby Church of England Voluntary Aided Primary School	York
Whitchurch CofE Primary School	Herefordshire
Whitecote Primary School	Leeds
Woodcock's Well CofE Primary School	Cheshire East

Secondary schools	**Local authority**
All Saints CofE School	Stockton-on-Tees
Allerton Grange School	Leeds
Archbishop Holgate's School	York
Archbishop Temple School, A Church of England Specialist College	Lancashire
Balcarras School	Gloucestershire
Barnwell School	Hertfordshire
Beaminster School	Dorset
Bishop Challoner Catholic Secondary School	Hampshire
Bishopshalt School	Hillingdon
Bristnall Hall Technology College	Sandwell
Broughton Hall High School, A Technology College	Liverpool
Brownedge St Mary's Catholic High School	Lancashire
Bury St Edmunds County Upper School	Suffolk

Calderstones School	Liverpool
Callington Community College	Cornwall
Camborne Science and Community College	Cornwall
Cams Hill School	Hampshire
Cockshut Hill Technology College	Birmingham
Copthall School	Barnet
Court Moor School	Hampshire
Cove School	Hampshire
Cramlington Learning Village	Northumberland
Crofton School	Hampshire
Crown Hills Community College	Leicester
Driffield School	East Riding of Yorkshire
Durrington High School	West Sussex
East Barnet School	Barnet
Finchley Catholic High School	Barnet
Four Dwellings High School	Birmingham
Framwellgate School Durham	Durham
Gladesmore Community School	Haringey
Glenthorne High School	Sutton
Gosforth Central Middle School	Newcastle upon Tyne
Great Sankey High School	Warrington
Hailsham Community College	East Sussex
Hardwick Middle School	Suffolk
Harris Academy At Peckham	Southwark
Heart Of England School	Solihull
Holly Lodge Girls' College	Liverpool
Horsforth School	Leeds
Huntington School	York
Kettlethorpe High School, A Specialist Maths and Computing College	Wakefield

Kidbrooke School	Greenwich
King Edward VI Church of England Voluntary Controlled Upper School	Suffolk
Kirkby Stephen Grammar School	Cumbria
Knutsford High School	Cheshire East
Lake Middle School	Isle of Wight
Leysland High School	Leicestershire
Malton School	North Yorkshire
Manhood Community College	West Sussex
Marlborough School	Hertfordshire
Marshland High School	Norfolk
Millais School	West Sussex
Nab Wood Middle School	Bradford
Netherthorpe School	Derbyshire
Ponteland Community High School	Northumberland
Poole Grammar School	Poole
Prendergast-Hilly Fields College	Lewisham
Queens Park Community School	Brent
Ralph Sadleir Middle School	Hertfordshire
Rickmansworth School	Hertfordshire
Ripon Grammar School	North Yorkshire
Rodborough Technology College	Surrey
Rydens School	Surrey
Settle College	North Yorkshire
Settlebeck High School	Cumbria
Sir John Nelthorpe School–A Specialist Technology College for Science, Mathematics and Computing	North Lincolnshire
Sir William Borlase's Grammar School	Buckinghamshire
South Molton Community College	Devon
St Damian's RC Science College	Tameside

St Francis Xavier's College	Liverpool
St James' Catholic High School	Barnet
St John Fisher Catholic High School	North Yorkshire
St Joseph's RC High School and Sports College	Bolton
St Katherine's School	North Somerset
St Mark's Catholic School	Hounslow
St Mary's Catholic Comprehensive School	Newcastle upon Tyne
St Michael's Roman Catholic Voluntary Aided Comprehensive School	Stockton-on-Tees
Stoke-by-Nayland Middle School	Suffolk
The Bishops' Blue Coat Church of England High School	Cheshire West and Cheshire
The Ellen Wilkinson School for Girls	Ealing
The Honywood Community Science School	Essex
The John Warner School	Hertfordshire
The King's School (the Cathedral School)	Peterborough
The McAuley Catholic High School	Doncaster
The North School	Kent
The Purbeck School	Dorset
The Thomas Alleyne School	Hertfordshire
The Windsor Boys' School	Windsor and Maidenhead
The Winston Churchill School A Specialist Sports College	Surrey
Thomas Hepburn Community Comprehensive School	Gateshead
Upper Shirley High School	Southampton
Waldegrave School for Girls	Richmond upon Thames
Willingdon Community School	East Sussex

Special schools	**Local authority**
The Alternative Centre for Education	Brighton and Hove
Nunnykirk Centre for Dyslexia	Northumberland

Further education and sixth form colleges	Location
Alton College	Alton
Aylesbury College	Aylesbury
Barton Peveril College	Eastleigh
Cadbury Sixth Form College	Birmingham
Cheadle and Marple Sixth Form College	Stockport
Christ The King Sixth Form College	Lewisham
City of Westminster College	Westminster
East Norfolk Sixth Form College	Great Yarmouth
Gateway Sixth Form College	Leicester
Greenwich Community College	Greenwich
Harrow College	Harrow
Hartlepool Sixth Form College	Hartlepool
John Ruskin College	South Croydon
Leyton Sixth Form College	Leyton
Loreto College	Manchester
New College Telford	Telford
Orpington College of Further Education	Orpington
Portsmouth College	Portsmouth
Prior Pursglove College	Guisborough
Queen Mary's College	Basingstoke
Salford City College	Salford
Sir George Monoux College	Walthamstow
Southgate College	Southgate
Southwark College	Bermondsey
St Brendan's Sixth Form College	Bristol

St John Rigby RC Sixth Form College	Wigan
St Mary's College, Middlesbrough	Middlesbrough
Stockton Riverside College	Stockton-on-Tees
Stockton Sixth Form College	Stockton-on-Tees
The Sheffield College	Sheffield
Wirral Metropolitan College	Wirral

Annex B. Results in national assessments and public examinations

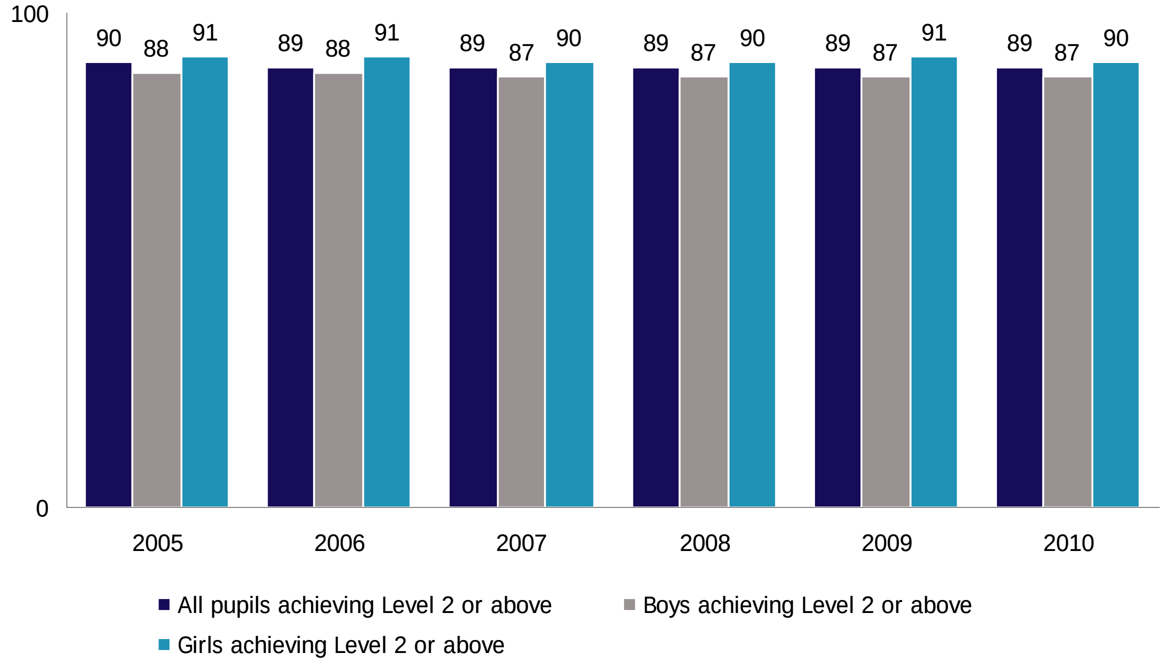
Standards in science in primary schools

National data from 2005 to 2010

Key Stage 1

Between 2005 and 2010, there has been very little change in the proportion of pupils achieving Level 2 or above in Key Stage 1 teacher assessments; the proportion has remained at 89% since 2006. The same picture is evident for gender. However, the proportion of girls achieving Level 2 or above has remained at least three percentage points higher than that for boys between 2005 and 2010. There has been a gradual decline in the total number of pupils in Key Stage 1 over the period of this report and a consistent fall in the number of pupils involved in Key Stage 1 teacher assessments from 559,800 in 2006 to 533,000 in 2009.

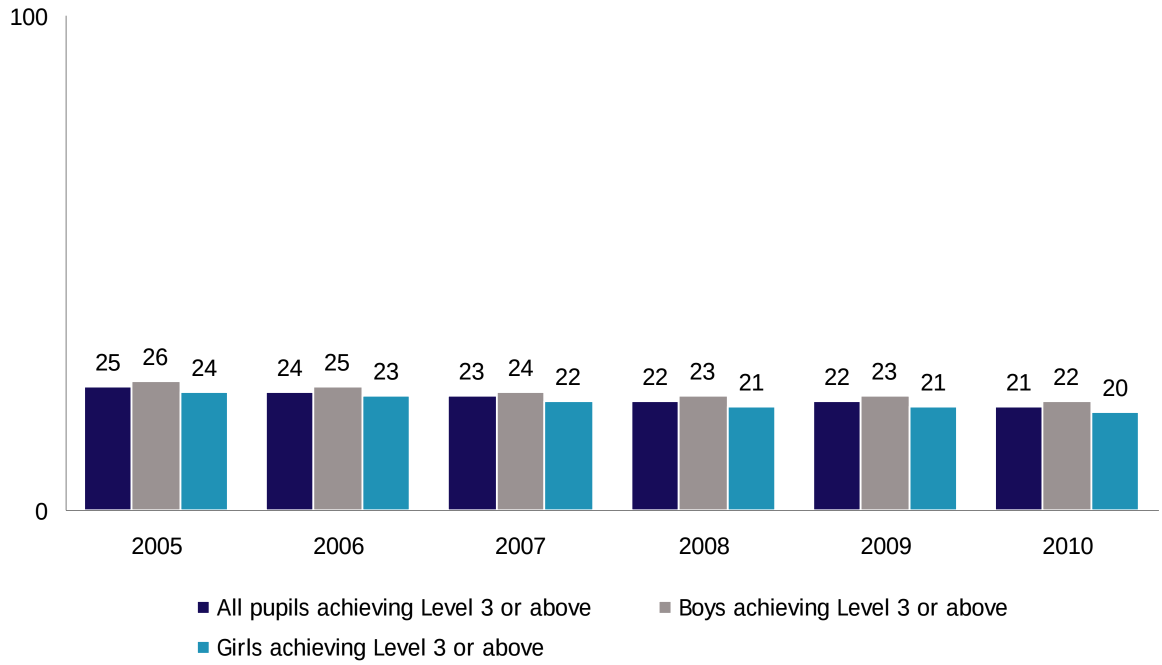
Figure 1: Percentage of pupils achieving Level 2 or above in Key Stage 1 science teacher assessments, 2005 to 2010



Source: DfE SFR26/2010: National Curriculum Assessments at Key Stage 1 in England, 2009/10 (Provisional).

Since 2005, there has been a steady decline in the proportion of pupils achieving Level 3 or above in Key Stage 1 teacher assessments, falling from 25% to 21%. Similar patterns were seen for boys and girls. However, the proportion of boys achieving Level 3 or above has been consistently two percentage points higher than that for girls.

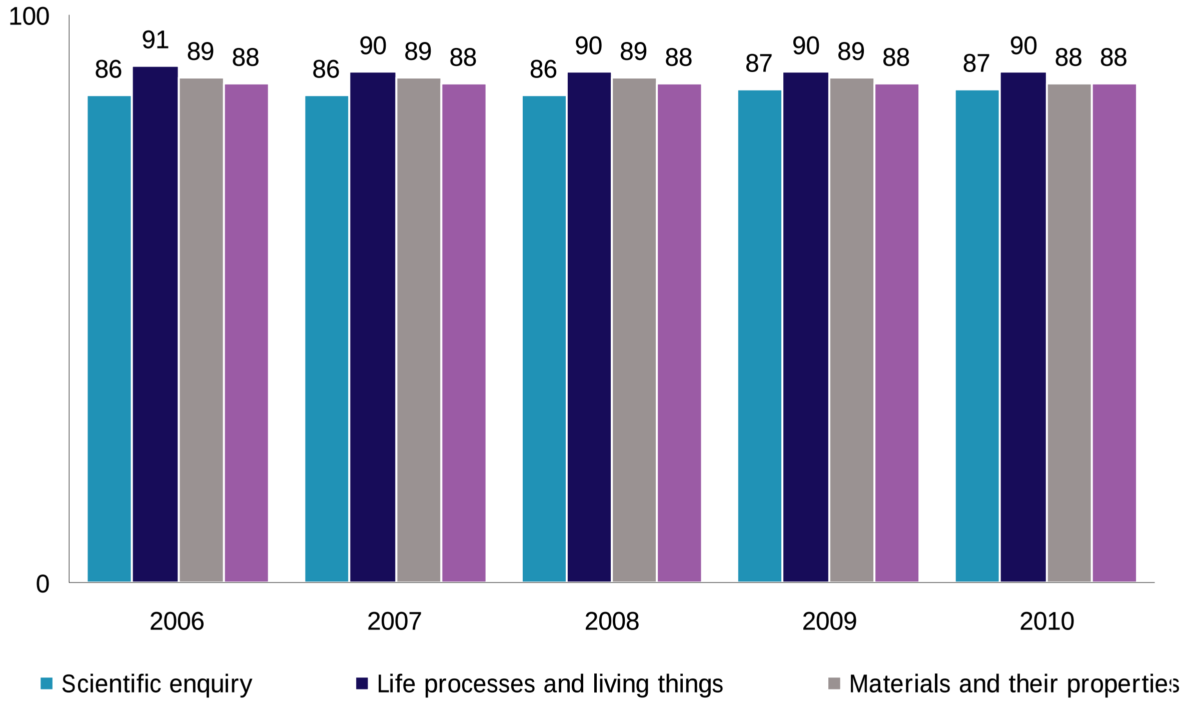
Figure 2: Percentage of pupils achieving Level 3 or above in Key Stage 1 science teacher assessments, 2005 to 2010



Source: DfE SFR26/2010: National Curriculum Assessments at Key Stage 1 in England, 2009/10 (Provisional).

The proportion of pupils achieving Level 2 or above in the four attainment targets has been steady between 2006 and 2010. Scientific enquiry has the lowest proportion of pupils achieving Level 2 or above at 87% in 2010 compared with 90% of pupils achieving Level 2 or above in life processes and living things.

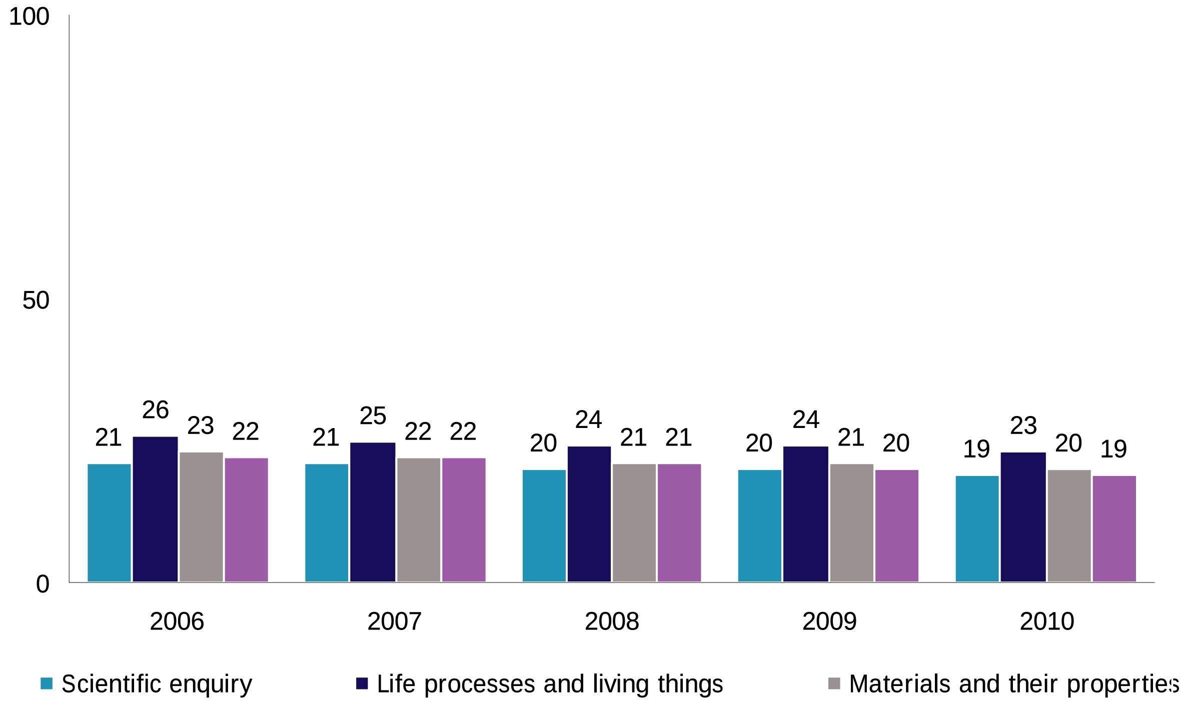
Figure 3: Key Stage 1 science teacher assessments of pupils gaining Level 2 or above between 2006 and 2010



Source: DfE SFR26/2010: National Curriculum Assessments at Key Stage 1 in England, 2009/10 (Provisional).

The proportion of pupils achieving Level 3 or above in each attainment target has changed very little between 2006 and 2010. The proportion of pupils achieving Level 3 or above in scientific enquiry was the lowest of the four attainment targets while life processes and living things has the highest proportion of pupils achieving Level 3 or above.

Figure 4: Key Stage 1 science teacher assessments of pupils gaining Level 3 or above between 2006 and 2010

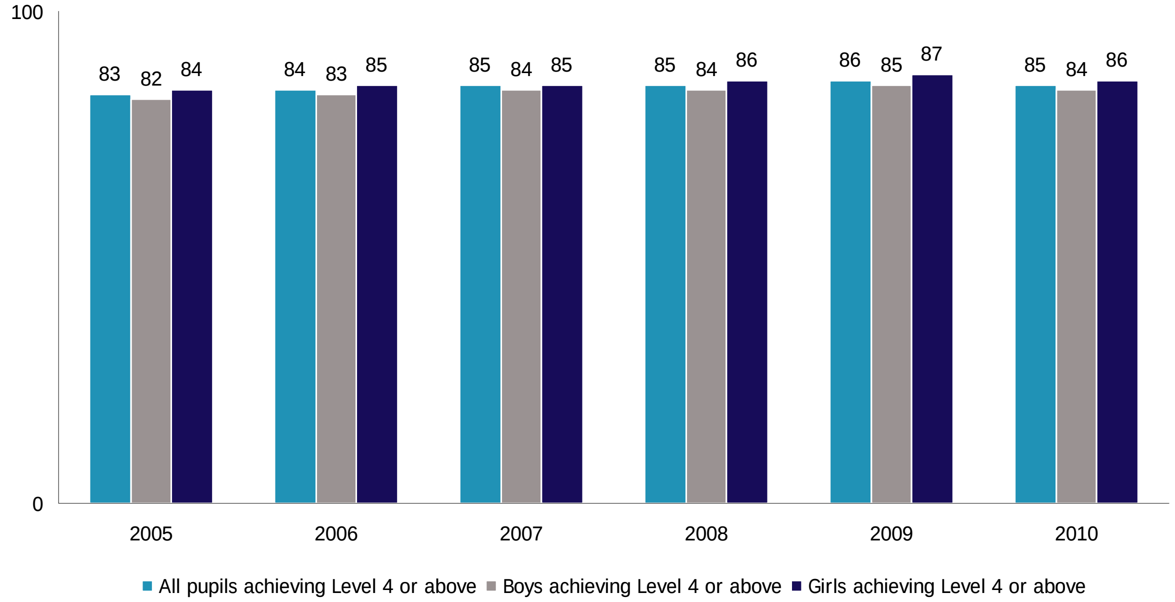


Source: DfE SFR26/2010: National Curriculum Assessments at Key Stage 1 in England, 2009/10 (Provisional).

Key Stage 2

The proportion of pupils achieving Level 4 or above in Key Stage 2 teacher assessments rose slowly between 2005 and 2009 from 83% to 86% but dropped to 85% in 2010. This trend can be seen in data for both boys and girls. As with Key Stage 1 teacher assessments at Level 2 or above, the proportion of boys who achieve Level 4 or above has been about two percentage points below that of girls since 2005. The total number of pupils whose performance was teacher assessed has risen steadily since 2006 (2005 pupil numbers were not included in the first statistical release for 2005). The biggest rise in the total number of pupils being assessed occurred in 2007 and 2008; the figure increased by more than 99,000 pupils.

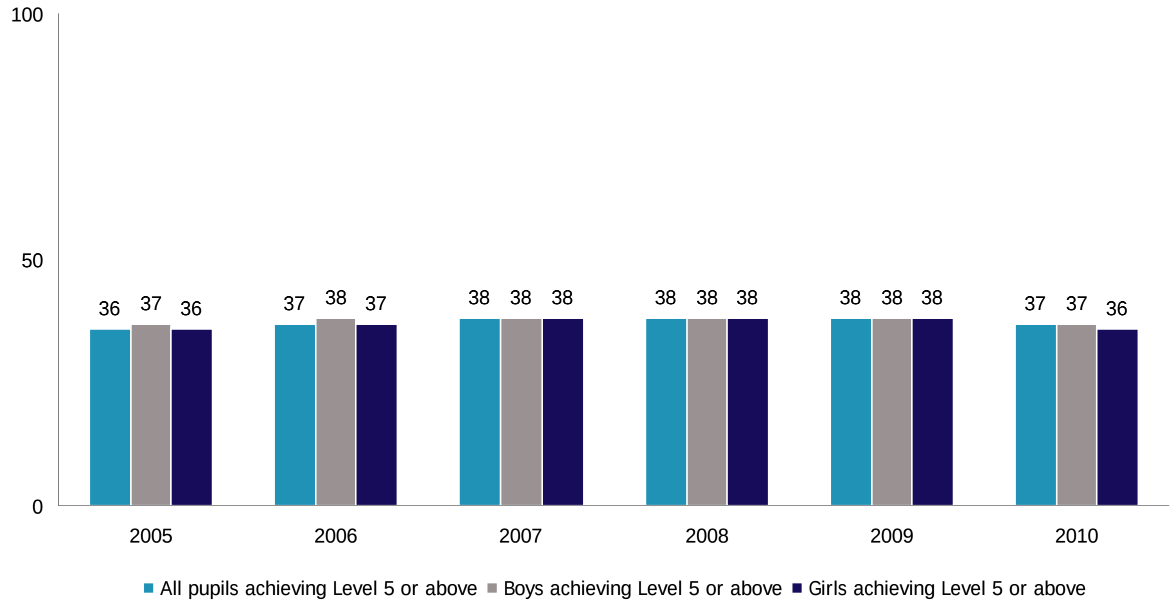
Figure 5: Proportion of pupils, by gender, achieving Level 4 or above in Key Stage 2 teacher assessments



Source: DfE National Curriculum Assessments at Key Stage 2 in England, SFR36/2010 (Revised).

The proportion of pupils achieving Level 5 or above remained at 38% between 2007 and 2009, having risen from 36% in 2005. It fell to 36% in 2010. Similarly, the percentage of boys and girls achieving Level 5 or above has been at 38% from 2007 to 2009, falling to 37% in 2010.

Figure 6: Proportion of pupils, by gender, achieving Level 5 or above in Key Stage 2 teacher assessments



Source: DfE National Curriculum Assessments at Key Stage 2 in England, SFR36/2010.

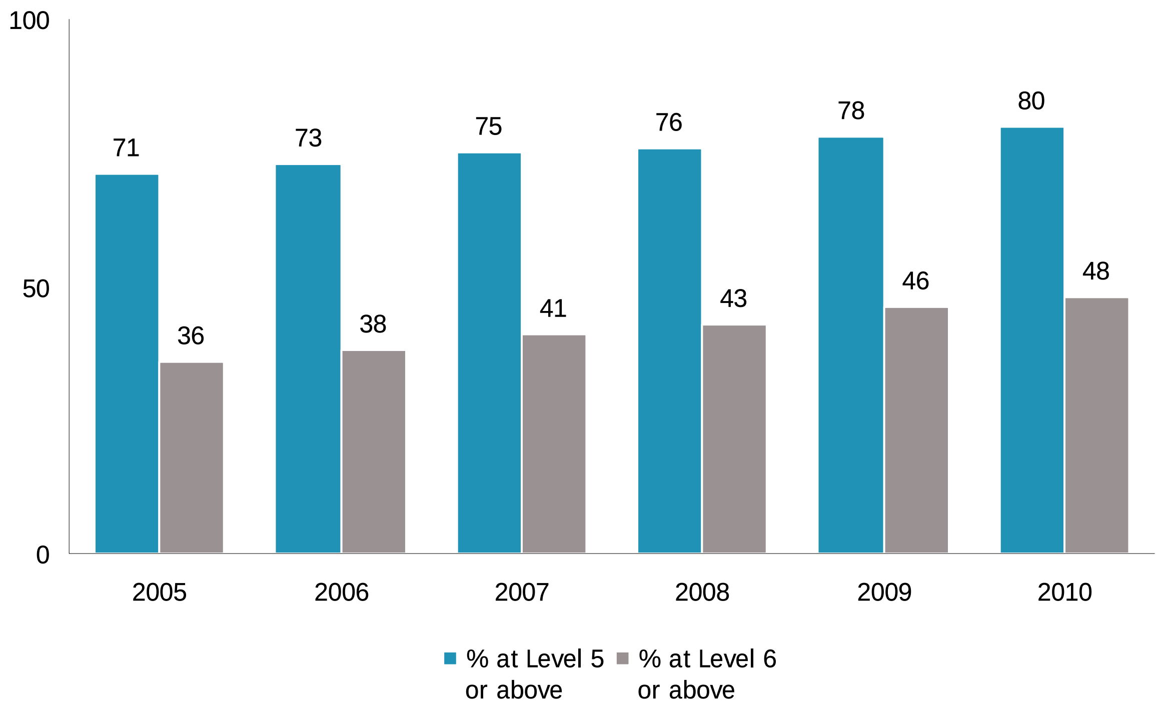
Standards in science in secondary schools

National data from 2005 to 2010

Key Stage 3

Key Stage 3 teacher assessments indicated that the proportion of students gaining Level 5 or above in science rose by nine percentage points, from 71% in 2005 to 80% in 2010. Attainment at Level 6 rose by 12 percentage points during the same period.

Figure 7: Percentage of pupils achieving Level 5 or above and Level 6 or above in science teacher assessments of core subjects, 2004/05 to 2009/10



Source: DfE National Curriculum Assessments: Teacher Assessments at Key Stage 2 and 3 in England, SFR23/2010.

Key Stage 4

In 2007/08, 491,600 students attempted core science for GCSE with 354,500 attempting additional science. The percentage of boys attaining A* to C in core science was 58% compared with 60% for girls. For additional science, 67% of boys and 69% of girls attained A* to C. For students studying individual sciences, including physics, chemistry and biology and individual GCSEs, A* to C attainment was above 90% for both boys and girls across the three subjects.

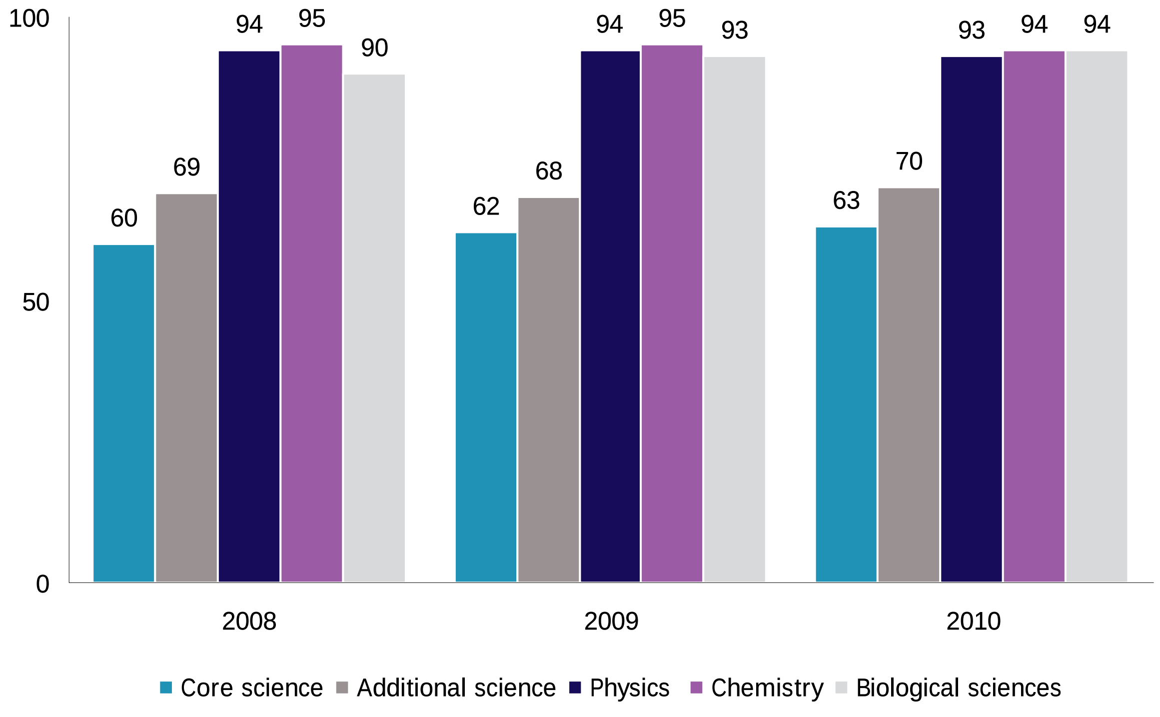
In 2008/09, 456,000 students studied core science for GCSE and 324,300 studied additional science. There was a rise in attainment at A* to C for boys and girls in core science by two percentage points to 60% and 62% respectively. Boys achieving

A* to C grades in additional science fell by two percentage points to 65%; similarly, girls' attainment fell by one percentage point to 68%. For individual sciences, attainment at A* to C saw little change except in biological sciences where girls' attainment rose by three percentage points to 93%.

In 2009/10, 404,900 students studied core science for GCSE and 288,500 studied additional science. There was a slight rise in attainment at grades A* to C for girls in core science and a two percentage point increase in additional science. While there was a slight increase for boys in additional science, attainment in core science had decreased by one percentage point. For individual sciences, attainment at A* to C saw little change.

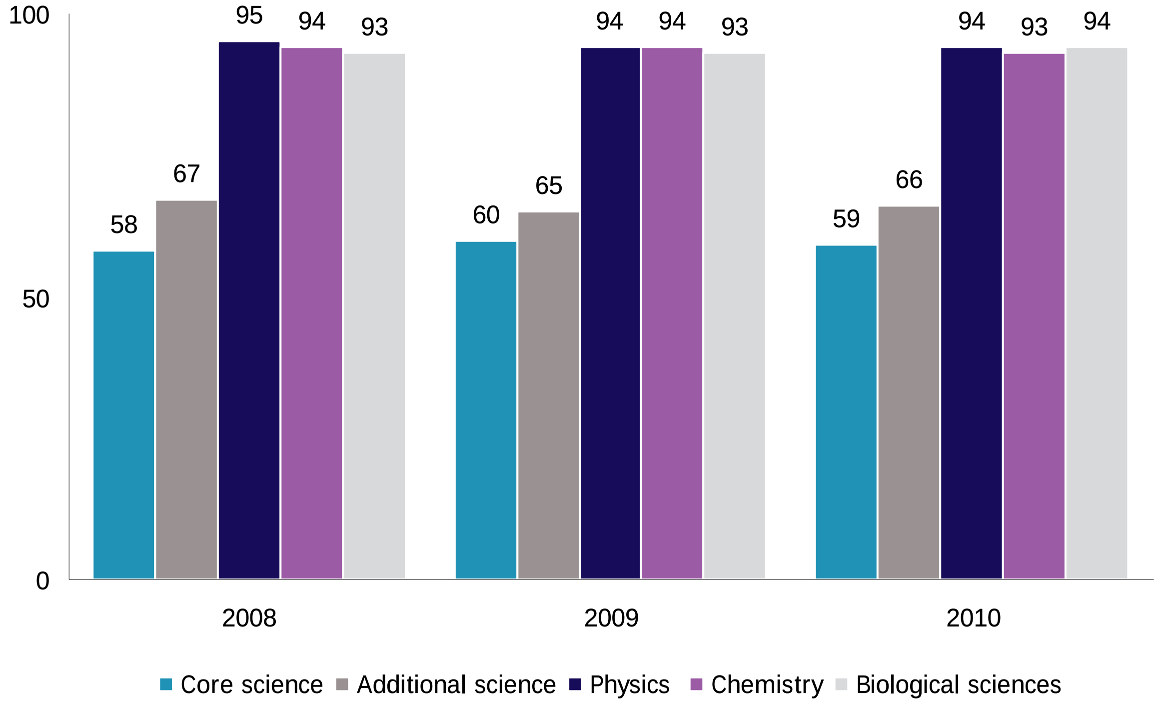
While the numbers of students attempting core science and additional science have both fallen, the numbers of students taking individual sciences have increased between 2007 and 2010: in physics from 67,300 to 112,100, in chemistry from 68,300 to 113,100, and in biology from 74,700 to 115,700.

Figure 8: GCSE attempts and achievements in selected subjects by girls at the end of Key Stage 4, 2008 to 2010



Source: DfE: GCSE and Equivalent Results in England, 2009/10 (Provisional), SFR30/2010.

Figure 9: GCSE attempts and achievements in selected subjects by boys at the end of Key Stage 4, 2008 to 2010



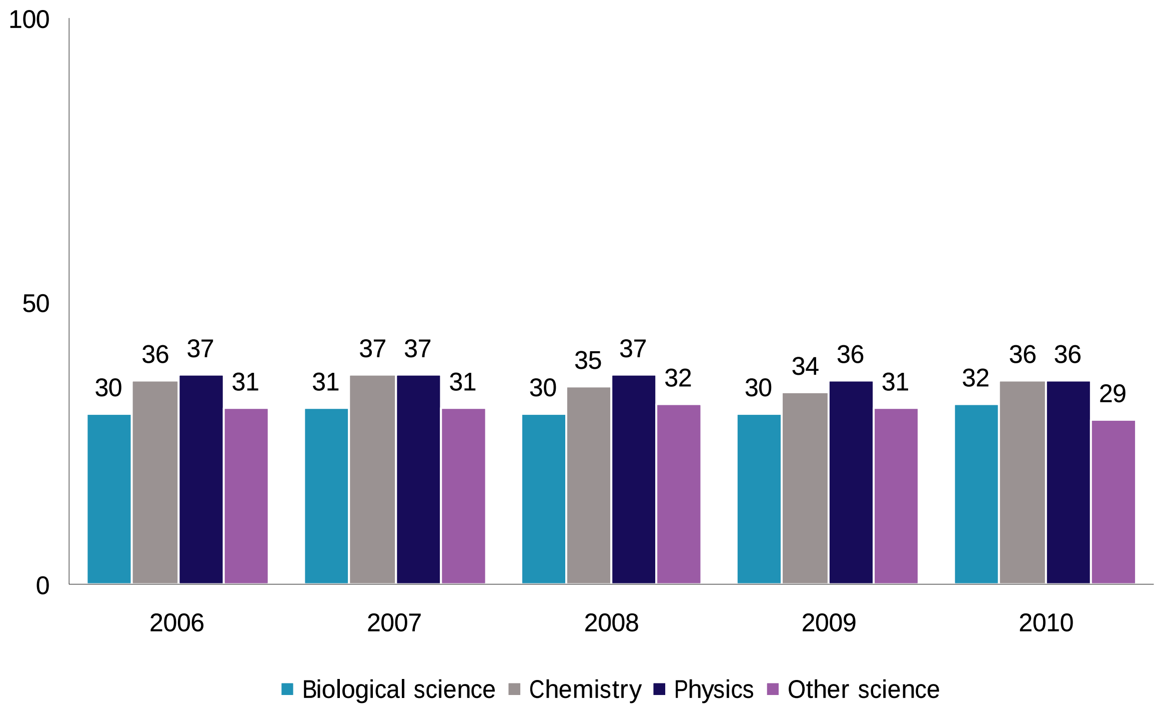
Source: DfE: GCSE and Equivalent Results in England, 2009/10 (Provisional), SFR30/2010.

Post-16

The proportion of students attaining A to E grades in all four AS-level science courses remained consistent between 2007 and 2010. For biological science, 81% of students attained the A to E benchmark, except in 2009 when 80% did so; 83% achieved the benchmark for chemistry and physics each year although in 2010 it increased to 84% in chemistry. Attainment for other sciences fell slightly from 82% in 2007 to 81% in 2010. Attainment has been consistent despite yearly rises to entries in biological science, chemistry and physics.

Girls outperformed boys in the proportion of students who achieved A to E grades in 2010 in all science AS levels, except for other science, where the proportion of boys who gained A to E grades was equal to that of girls at 82%.

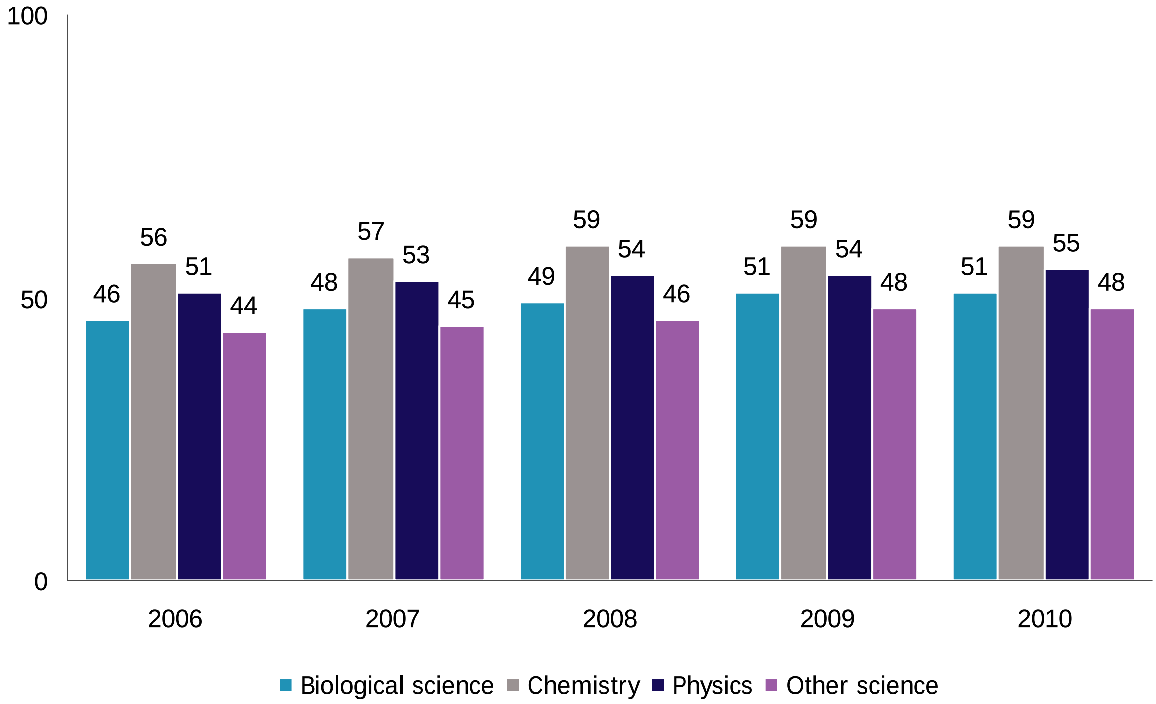
Figure 10: Percentage of learners who achieved A or B grades in AS-level biological sciences, in schools and colleges, 2006 to 2010



Source: DfE: GCE/Applied GCE A/AS and Equivalent Examination Results in England, 2009/10 (Provisional), SFR31/2010.

A-level results at grades A to E in 2010 were higher than those at AS level, with all sciences above a 97% A to E achievement rate. Since 2006 there has been a steady increase in the proportion of students achieving A to E grades for all science subjects. Girls' attainment at grades A to E was, again, slightly higher than that for boys for all years between 2006 and 2010.

Figure 11: Percentage of learners who achieved A or B grades in A-level sciences in schools and colleges, 2006 to 2010.



Source: DfE: GCE/Applied GCE A/AS and Equivalent Examination Results in England, 2009/10 (Provisional), SFR31/2010.

Written evidence submitted by Jill Friedmann (Sch Sci 45)

I watched the Select Committee hearing at which evidence was taken from teachers and members of NUT and NAS/UWT etc. I am pleased this is being discussed and the evidence given certainly supports what I experienced as a science teacher, now retired since January.

I would like to add some additional points for your consideration.

1 **Technicians**. The point was well made about the need for a career structure and proper pay for this group. It is hugely stressful when teachers have to do the technician work as well or have to put up with willing but untrained staff. It is also dangerous to use unqualified staff even at Key Stage 3.

2 **Facilities** in many schools for doing practical science are poor. Labs are often too small and badly laid out, not enough sinks, power points, shelving for bags and coats. Poor acoustics.

3 **Equipment**. Again , this is often inadequate. Too much sharing, broken equipment often due to poor manufacturing standards and inadequate maintenance.

4 **CPD** You might look at how many teachers ever get to go to the ASE annual conference. This is an excellent place to network with other teachers and to hear about up to date research. I was lucky in that my school paid for me to go to this 3 day event but over the years I suspect fewer and fewer teachers go due to costs and refusal of schools to pay for supply cover when the conference happens to fall in term time. It is not satisfactory that most teachers are denied access. Most attendees work in science education but not in the classroom. Attending locally run courses is good but real inspiration comes from attendance at the ASE.

5 **Access to science advisers**. What a great loss now that we have lost our advisory teams. For years Leicestershire had a good group of science advisers who were happy to come out into schools and lend a hand.They were a great asset.

6 **Class size**. Why are some Design classes smaller than science classes? Maybe this dates back to an era when there was less hands on science. Running a practical for a class of 30 Key stage 3 pupils is hard work and there isn't really time to have the level of discussions with small groups as one would wish. It is the only way of understanding their misunderstandings. Larger classes also means that often the teacher is reduced to onlooker- keeping an eye on safety, sorting broken equipment. Also, it's worth remembering that we are still largely teaching mixed ability groups at this age which is manageable if the group is small enough.

7 **Classroom assistants**. They are essential with some KS3 classes due to the large number of SEN children with a variety of special needs from learning to behavioural difficulties. We need more training for these assistants (science training). It's not good enough that much of the time SEN pupils are receiving their support from unqualified staff with poor science educational background.

8 **SATs** at KS3 seem to have wreaked havoc with primary science. What a loss. Look at how these pupils are spending year 6.

9 **School trips**. Cost is always a problem but also staffing. CRB checks have made it more difficult in the past to enable the school cleaner or a willing parent to come along as an extra. You might also take a look at the cost of visits to science based museums. I am very pleased that most art galleries are free but why must we pay for science (those of us outside of London). This is part of a bigger problem about access to science museums for the general public and I see no justification for charging.

We need to get this right. It's not just about creating the next generation of scientists -most people are not going to be academics or researchers. However, many will work in a science environment, all need to develop their analytical skills and ability to evaluate evidence/data for everyday life if they are to become scientifically literate citizens. we must not allow the academic examinations system to distort science education but we must provide stimulating experiences for those that might go on to become scientists. I welcome the attempts at increasing the uptake of triple science. KS3 SATs really caused the demise of much practical work with teachers being harrassed to produce ever improved results it is not surprising that many ditched practical work in the mistaken belief that this would yield better results.

I look forward to reading your final report,

Jill Friedmann

23 June 2011

Written evidence submitted by University of Bradford (Sch Sci 46)

1. Summary:

1.1. An essential component of practical science is the innovation and creativity required to test an idea.

1.2. It should be possible to deliver practical science over the web, and retain with the student the creativity required to test the idea and the data processing skills.

1.3. Uniquely the Bradford University Robotic Telescope(BRT) uses a robotic system to collect data for use by students from the age 10 (key Stage 2) upwards enabling the students to retain the essential innovative and creative approach required for practical science. Although this system only works in a limited area of science it is able to challenge the students with the innovation and creativity required for practical science.

1.4. The Bradford University system has over 55,000 school users mainly in West Yorkshire and is slowly being taken up in other areas of the country.

1.5. Continuing funding opportunities for this work in the new educational landscape have not yet been finalised.

1.6. There is international interest in the system particularly in China and Poland.

2. Recommendations for Consideration

2.1. Web delivery of practical science similar to the Bradford Robotic Telescope should be considered as a base level practical science experience for all students. Practical support is required to encourage schools across England to include the BRT in their curriculum.

2.1.1. It is low cost and there is considerable research data to show it is inspirational in the classroom motivating for the students, raising aspiration and achievement in STEM subjects.

2.1.2. The BRT standard delivery with the teacher in the classroom, provides effective teacher professional development in subject knowledge and the use of ICT in the classroom. It is most effective starting with primary year 5 children.

2.2. The expansion of the web approach to practical science to deliver more of the syllabus should be investigated beyond the initial programmes with Shell and Drax.

3. My Background:

3.1. My name is John Baruch. I am a practising scientist and academic in the School of Informatics at the University of Bradford. My Background is Astronomy, Astrophysics and Cybernetics, currently all combined in a programme of research into, and delivery of, practical science in schools and the necessary CPD for the teachers. I am director of Robotic Telescopes at the University of Bradford and lead the robotic telescope team there working closely with the University STEM programme.

3.2. I am convinced from the earlier reports of the Houses of Parliament which included the teaching of science and other reports from the UK government, the World Bank and others on the development of the Knowledge Economy that practical science has a vital role to play in developing an innovative and creative workforce, a population that understands how science works and embraces science as an essential component of future prosperity. Most importantly it is an essential component of energising the brightest young people with science and inspiring them to devote their careers to science or its associated areas of engineering, maths, technology and medicine.

3.3. Detailed analysis of the reports referred to above and many years of practical experience with students teaching practical science subjects convinces me that:-

3.3.1. Practical science teaches the student to develop an approach learning through investigation which requires ideas and explanations to be tested by experiment.

3.3.2. The nature and quality of the student experience in primary school is critical. Very few primary teachers are science based. Most completed their science education with a double science GCSE which included a very limited amount of physics or practical science. Poor quality science teaching at primary schools alienates many students, preventing them from building on interests in space and dinosaurs which captivate them in their earlier years.

3.3.3. The limiting science experience at primary school is compounded with a significant decline in practical science experience in secondary schools. This is partly due to declining numbers of science teachers teaching their own science specialism.

3.3.4. The limiting effects of both primary and secondary experiences contribute to the continuing decline in number and quality of the STEM applications to University, and probably to a declining understanding of science and enthusiasm for science amongst English citizens generally.

3.3.5. In my opinion, the heart of this decline can be attributed to the disappearing practical science experience at both primary and secondary school.

4. Submission

4.1. Delivering Practical Science

4.1.1. The essential component of practical science is the innovative and creative approach required to think of experiments that will test out theories for example: why the Moon changes its shape over the month or why so few trees have leaves with colours other than green.

4.1.2. The current traditional model of delivering practical science in schools is very expensive. It requires extensive training of the teachers, the provision of laboratories, equipment and trained laboratory staff. This traditional way of delivering practical science is in the laboratory supplemented with demonstrations by the teacher.

4.1.3. We now have the ability to deliver practical science over the web in the area of space and astronomy. We should be able to include the key innovative and creative core of developing experiments for all the sciences to test out ideas with simulations and games, to formulate and express ideas, and robots to perform experiments as instructed by the student to test out the ideas and return the data to the student for analysis and comparison with the predictions or otherwise of their original ideas.

4.1.4. Currently the only area of science where it seems to be possible to deliver practical science over the web at a greatly reduced cost, but still involving the students in the basic innovative and creative processes of experimental practice, is in astronomy.

4.1.5. However collaboration in small pilot programmes with Drax power station and a NESTA funded programme with the Shell Moss Moran plant in Fife showed that it is possible to extend the web experience of practical science far beyond astronomy.

4.1.6. Bradford University operates the only robotic web based practical science education programme, anywhere in the world. http://schools.telescope.org/ . It is supported by an autonomous robotic telescope in Tenerife which operates in a service mode taking the requested observations and returning the data back to the students. The programme is designed to be related to, and relevant to, the National Curriculum programme of all children in the UK. It is accompanied by a professional development programme for the teachers and is delivered to primary school pupils from age 10, and in secondary schools to pupils up to the age of 18 including GCSEs and A levels. There are currently over 55,000 pupils and 1,800 teachers whose schools have paid for them to use the resource. Data from the resource are also used to support maths and physics teaching and are used in many schools in art and English for creative writing and space pictures around different cultural mythologies.

4.2. Funding

4.2.1. A significant number of these school subscriptions to the Bradford Robotic telescope have been paid for by science charities like the Ogden Trust, by Local Authorities and education programmes like Aim Higher, STEM, Gifted and Talented, who are all enthusiastic about this resource. The new education landscape is leading to a re-evaluation of potential funding streams.

4.3. Impact

4.3.1. Research funded by the Astra Zeneca Science Teaching Trust and others has shown:-

4.3.2. **Pupil Interest and Engagement:** A significant change in the attitudes to science of the pupils who have met the Bradford Robotic Telescope in their primary school. In contrast to non-involved schools, there was not decline, but a general maintenance, of the positive attitude to science, with a 5% increase in those who intend to choose a science subject after GCSE. This work used the York University “Year 9 Attitudes to Science National Survey” questionnaire. The report is available on request from the Robotic Telescope Group at the University of Bradford.

4.3.3. **CPD:** The BRT project CPD for primary teachers uses science enthusiasts to introduce the robotic telescope, the ICT and the science to the pupils with the teacher in the classroom. This was much more effective than the traditional models of CPD which rely on central training either by Local Authority or by feeder secondary school and where the CPD is delivered without the pupils being present. The effectiveness of the BRT project CPD was evaluated by looking at the use of the education resource in the weeks and months after the training. With class based CPD there was an average of 7 days when the class continued to use the resource in the 3 months following the CPD and a further 33 days when at least one member of the class used the resource. This is in stark contrast to other methods of training where there is hardly any use at all of resources after the training days. The full report is available from the Robotic Telescope Group at the University of Bradford.

4.3.4. **University Applications** Analysis of the applications to the University of Bradford STEM departments for September 2010 showed an average 30% increase in applications from schools where the children had met the Bradford Robotic telescope(BRT) earlier in their education compared to applications from schools where the BRT was not part of the curriculum.

4.4. Extension and Collaboration

4.4.1. The Robotic Telescope group have now signed agreements with other Universities, including Imperial College London, to extend the participating schools from West Yorkshire to the South East and London as part of the Imperial College outreach programme and with Glasgow University to deliver the practical science in Scotland. Discussions are continuing with other universities in the UK.

4.5. International Work

4.5.1. There are over 35,000 other users around the world. The British Council funded the translation of the BRT Education Materials into Chinese and presentations have been made at a number of Chinese schools mainly in Guangzhou and Shanghai.

4.5.2. The Chinese do not teach practical science in their normal school curriculum. They are very concerned to build a knowledge economy and to develop an innovative and creative workforce. Inspired by the practical science work with the Bradford Robotic Telescope I received an invitation earlier this year to join a pilot project working with the education authorities of Guangdong, Guangzhou, Shenzhen, Hong Kong (Pearl River Delta) and the Beijing Postgraduate University to develop practical science in Chinese schools. I am now working to link the UK Royal Society, Association for Science Education, British Science Association, the Institute of Physics, the Royal Society of Chemistry and the Society of Biology in a programme to develop practical science in the Pearl River Delta schools. The initial plan is to translate suitable UK science posters and get them into all their school laboratories, to start a British Science Association CREST type of programme, to run a practical science competition for their schools in November 2011, developing into a Big Bang type of event. These are the first steps towards including practical science in their education from primary school upwards.

4.5.3. An approach along the lines of the Chinese development has been received from Poland. They seem to be lacking funding and have asked me to support an application to the British Council to work with us using the Robotic Telescope in Polish.

Note: I apologise for this note being late in submission. I was in China touring around schools looking at their lack of science education and discussing the problem with science teachers.

John Baruch
School of Informatics
University of Bradford

26 June 2011

Supplementary evidence from Greg Jones (Sch Sci 47)

1. Risk assessments are an essential part of science experiments but they should not be "set in stone" but amended in the light of changing circumstances. They are analogous with security at Portcullis House, Westminster, which has changed significantly over the years in response to the threats to our society from terrorism. In the light of new knowledge, new procedures have been put in place to minimise the risks to all and, as with risk assessments, are reviewed regularly.
2. There are too many examples of risk assessments for certain experiments available. What would improve the situation is that a generic one should be drawn up for each experiment, sent to every exam board to be incorporated with their appropriate syllabus and then adapted by each institution for their particular laboratory circumstances.
3. These generic risk assessments could be drawn up by practicing scientists within such bodies as the Association for Science Education, the Institute of Physics, the Royal Institute of Chemistry, the Institute of Biology and the Institute of Education. These risk assessments should then be sent to the exam boards for them to incorporate with their science syllabi before being sent to schools and colleges for their adaptation.
4. The effect of having such generic risk assessments, for all the experiments that will be covered by exam syllabi, would be to stop science teachers "re-inventing the wheel" and to have a base level of compliance for assessing experimental risks.
5. The use of Information Technology (IT) equipment within science lessons is as a tool which supports the teaching and learning. They can be used for a variety of activities; from dataloggers and visual measuring devices to interactive whiteboards and experiment simulators.
6. Using IT within science can also encourage the development of important research skills, which are an essential part of scientific investigations at both GCSE and A Level, but it should never replace or detract from the carrying out of actual practical scientific experiments.
7. The amount of money that school/college Science Departments have to spend on IT or are allocated as part of the overall IT budget within the institution is extremely variable. Consequently, the amount of IT used within science lessons is also variable.
8. In spite of this, the minimum requirements of IT and its use within science lessons is laid down by exam board syllabi but I feel that amount of IT needs to be increased still further if schools/colleges are to prepare students adequately for studying a University science course.
9. During school/college refurbishment programmes, often the question that is asked is "what kind of science lab provision is needed in the future?" Too often the answer from Head teachers is that "Science can be carried out in a normal classroom." New school buildings, especially under PFI/new build academies, have tended to cut corners on science lab specs to keep costs down.

10. This kind of attitude further erodes the possibilities of carrying out practical scientific experiments/investigations by students in an appropriate setting and leads to more theory work, and consequently less practical work, in science lessons.
11. Science teachers are good role models for students as they illustrate the skills that are needed in a particular workplace. Practical skill is just one of the main tools that teachers have in their "toolbag" but the size and complexity of that skill has diminished over time due to the constraints of exam syllabi and the perceived need to "teach to the exam".
12. The consequence now is that students who become teaches are less confident in doing practical work in science lessons, so less practical work is done. This downward spiral can only be reversed by increasing the amount of practical work that needs to be done and as a result teacher confidence in doing practicals/experiments will increase accordingly. The change to Initial Teacher Education (ITE) requirements in 2007 meant an increase in the amount of time spent on teaching practice, with a consequent reduction in the time spent with the ITE provider. This has certainly lessened opportunities for trainee teachers to practice their skills. If not much practical work is going on at their placement schools, trainees may have hardly any chance to become confident in taking practical classes themselves.
13. Fun for both teachers and students needs to be put back into science, particularly at Key Stages 4 and 5. Teachers and students can have fun together by doing more experiments, improving their practical/experimental skills and increasing their ability to learn more science through practical investigations.
14. Time is needed to develop any skills and practical ones need as much, if not more, as most others. But that time can only come from "freeing up" the science curriculum, by reviewing and reducing the content of all science exam syllabi and by making them more modern, interesting and practically based.
15. Field trips are beneficial to both students and teachers alike as they improve working relationships, encourage teamwork, promote problem solving, consolidate teaching and learning as well as create fun and interest.
16. For students, field trips often result in a better attitude to work, to the subject and to the teachers involved as well as an increased maturity for some individual students - all of which are beneficial for making them better scientists.
17. All teacher training courses, whether carried out through Universities or through schools/colleges, need to be revised to free up time for student teachers/Newly Qualified Teachers to practice their experimental skills on a weekly, if not daily, basis.
18. Education is always changing and science curricula are no different. It would be better to change and then have no more change for a number of years in order that the result of that change can be consolidated and built upon. Teachers are not averse to change but "change for change's sake" and "changes every year" do not engender teachers to change.

Greg Jones

28 June 2011