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Science and Technology Committee

# Practical experiments in school science lessons and science field trips

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*Additional written evidence*

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# Written evidence

## 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 three years, before that I spent two 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 three teachers are needed to take our cohort of 60 pupils away for three days, the school must pay for nine 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*

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## Written evidence submitted by Jane Giffould (Sch Sci 02)

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.

2(a) *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.

3(a) *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.

5(a) *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; and

(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. Two 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*

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

The Background to Practical Work in School Science

1. When physics and chemistry were first schooled in the mid-19th 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.

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

8. 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, eg, 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.

*The influence of health and safety concerns*

9. 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, eg 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.

*Examination Boards and practical work*

10. 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.

*Practical work, student performance and higher education*

11. 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.

*What changes should be made?*

12. 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.

*The experience of England in an international context*

13. 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, eg, 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*
Emeritus Professor of Science Education, Policy
University of Leeds

*5 May 2011*

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**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*

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# 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 (eg 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 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

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

[2] National Foundation for Educational Research (2004)

[3] TeacherVoice survey on behalf of the Council for Learning Outside the Classroom (2010)

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.
- — 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 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

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

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.

[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)

*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. 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*

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**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; and
- 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 2,000 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.[10] 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 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.

[10] 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

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.

*Professor Mary Ratcliffe*
Associate Director
Myscience

*10 May 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.

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?*

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.

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

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*

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## 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; and
- 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 teachers 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*

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

Q3. *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.[11]

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.[12]

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

*Matt Stalker*
Communications Manager
IChemE

*10 May 2011*

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[11] Not printed here
[12] Not printed here

**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; and
  - 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*

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**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% 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% 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 £7 billion.

### 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.[13] 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.[14]
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.[15] This resource is being provided free of charge to all UK secondary schools.

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

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.[16] 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 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.[17] 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.[18] 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.[19]
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 conceived, is narrowing the range of activities carried out in schools and reducing the learning on offer to students.[20] SCORE also believe that there is evidence that the current assessment demands are damaging practical science.[21]
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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Association of the British Pharmaceutical Industry

*11 May 2011*

[16] www.thelifesciencecentre.org.uk
[17] 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
[18] 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
[19] Information on Enthuse Awards is available at https://www.sciencelearningcentres.org.uk/centres/national/awards-and-bursaries
[20] 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
[21] Practical Work in Science, SCORE, December 2008, http://www.score-education.org/media/3668/report.pdf

## 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.

References (appended)

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Scott G W, Goulder R, Wheeler P, Scott L J, Tobin M L, Marsham S (2011a) The value of fieldwork in life and environmental sciences in the context of Higher Education: A Case Study in Learning About Biodiversity. Journal of Science Education and Technology. DOI 10.1007/s10956–010–9276-x.

Scott G W, Churchill H, Grassam M and Scott L J (2011b) Can the integration of field and classroom based learning enhance writing? The Life on Our Shore Case study. *Education 3–13*. In Press.

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*11 May 2011*

## Written evidence submitted by Oxford, Cambridge and RSA Examinations (OCR) (Sch Sci 18)

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*

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**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 (2007–08) 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*

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**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[22] 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[23] 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 increasing engagement and motivation in learners. The Teaching and Learning Research Programme,[24] 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,[25] 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

[22] Research Councils UK Public Engagement with Research Strategy http://www.rcuk.ac.uk/documents/scisoc/RCUKPERStrategy.pdf

[23] 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

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

[25] 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

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[26] 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",[27] which is designed to help secondary school teachers deliver some 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[28] 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[29] 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,[30] where researchers host a student within their institution. A

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

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

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

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

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

recent report from the National Audit Office[31] 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 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*

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## 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.

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

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 one-hour lecture you could spend eight hours filling in forms, writing letters, collecting money etc." (Secondary teacher)
>
> "School procedure requires six 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, ie 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*

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**Written evidence submitted by the Assessment and Qualifications 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; and
- 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 (AQA)

*11 May 2011*

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**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.

References

1. Eg 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. Eg London Outdoor Science project, BES school grounds project.

British Ecological Society

*11 May 2011*

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**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 three-dimensional structure from two-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, six 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 (2004–11) 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.

25. 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*

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**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,[32] of which more later. This Fair, referred to as The Big Bang, is now in its third year and is funded by over 20

[32] http://www.thebigbangfair.co.uk/home.cfm

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).

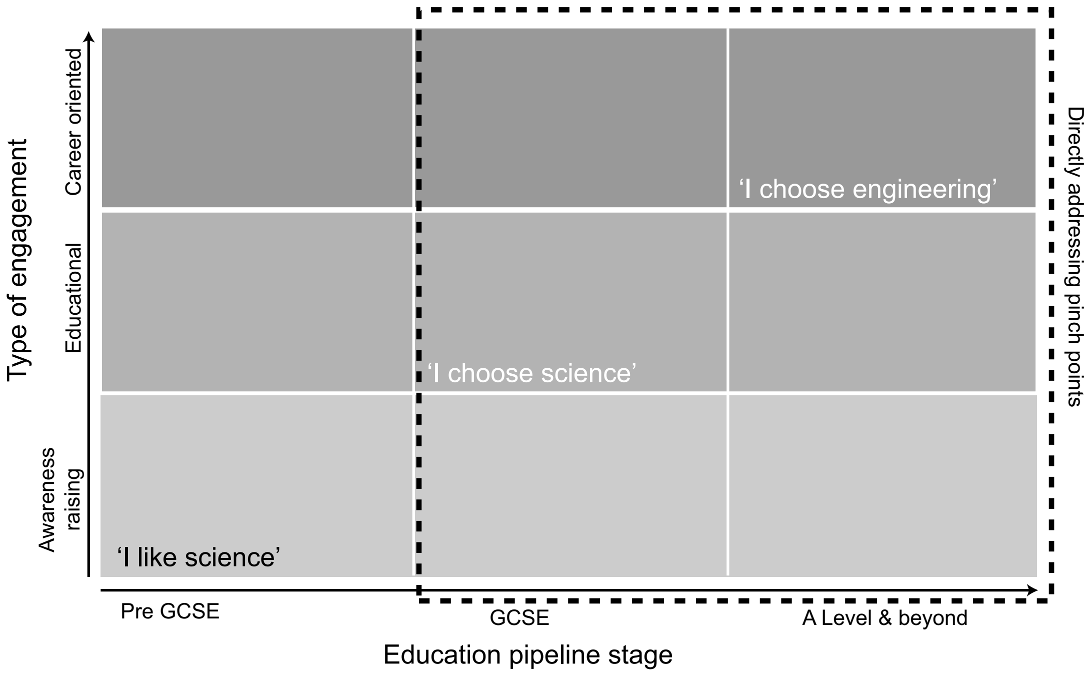
5. The engineering sector is already critically important to the UK economy, in March 2009 there were 482,880 engineering enterprises employing over 4.5 million workers and generating a combined turnover of £848.6 billion which equates to 19.6% of total GDP. In 2008 the manufacturing sector alone generated 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 2009–20 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 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.

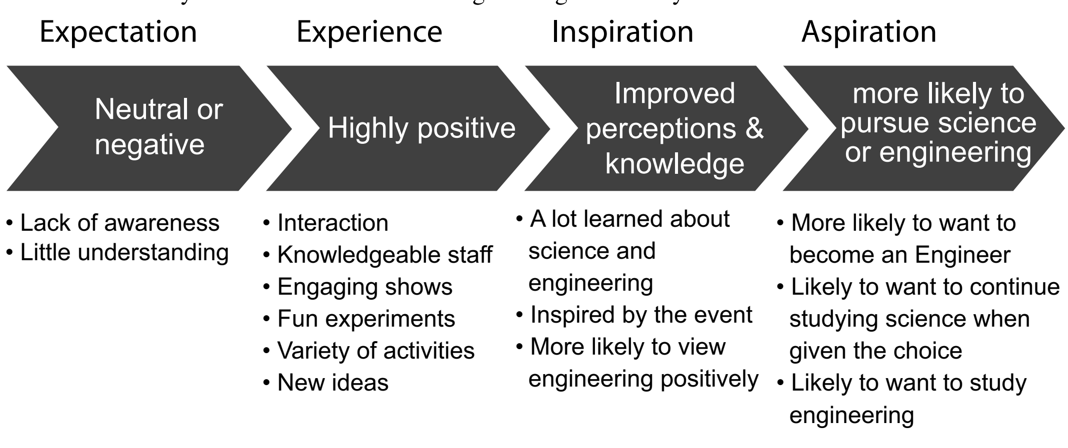
10. In its 2011 report, Building for Growth: business priorities for education and skills, the CBI identified the top priorities for schools and colleges. Top priority was improving employability skills (70%), with improving literacy and numeracy coming second at 65%.

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[33] 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.

[33] INCA: Dips in performance and motivation: A purely English perception? www.inca.org.uk/pdf/Final_Dip_Report.pdf

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.[34]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.[35]

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.

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[36]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[37]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/

We would be happy to supply further information to the inquiry in both written and verbal form as required.

[34] OECD 2007: PISA 2006 Science competencies for tomorrows' world Volume 1, Volume 2, Data and Analysis: Paris

[35] Educating the next generation of scientists: House of Commons Committee of Public Accounts

[36] Learning outside the Classroom, October 2008

[37] http://www.thebigbangfair.co.uk/2011_sponsors.cfm

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

*Paul Jackson*
Chief Executive
EngineeringUK

*11 May 2011*

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**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.[38] 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.[39]

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38 Analysing Practical Science Activities to Assess and Improve their Effectiveness, Millar (2010) http://www.gettingpractical.org.uk/documents/APSsampleJan2010.pdf

39 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

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 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.[40]

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,[41] 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.[42] 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.[43]

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
Wellcome Trust

*11 May 2011*

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http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=4294971776
[41] Statistics taken from the Wellcome Trust's Evaluation of the Darwin Initiative (2010) Not publically available
[42] http://www.wellcome.ac.uk/News/2008/News/WTX052388.htm
[43] Statistics taken from the Wellcome Trust's End of Grant Report (2011) Not publically available.

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http://www.psqm.org.uk

Association of Science Education, Be Safe, 4th Edition (2010)

**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 (eg as accessed by field trips and other visits to see science in use);
- the presented world (eg in science museums, botanic gardens and zoos); and
- the virtual world (eg 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 2004–08 (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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*Dr Ian Abrahams, Professor Robin Millar* and *Mary Whitehouse*
University of York

*11 May 2011*

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### Ian Abrahams

Ian Abrahams is a lecturer in Science Education in the Department of Education at the University of York. His research interests are in the areas of practical work and teachers' attitudes to science education. He recently led the evaluation of the DCSF funded Getting Practical: Improving Practical Work in Science project.

### Ruth Amos

Ruth Amos is a lecturer in Science Education at the Institute of Education, University of London. Prior to moving to Institute, she taught in London schools for 11 years. Her research interests include global dimensions in education, learning outside the classroom, and collaborative partnerships between schools and informal educators.

### Robin Millar

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.

### Michael Reiss

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.

### Mary Whitehouse

Mary Whitehouse is Project Director for the Twenty First Century Science Project at the University of York. Her research interests are in the area of external assessment of science and physics. She has been Chief Examiner for GCSE Physics and GCSE Science as well as Principal Moderator for AS Physics at OCR.

## 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[44] (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[45] 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.[46]" 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.[47]

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 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[48]". 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[49].

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[50].

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"[51]. 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.

44 See www.geographyteachingtoday.org.uk/fieldwork
45 Geography: Learning to make a world of difference. Ofsted (Feb 2011)
46 Geography: Learning to make a world of difference pg 4 Ofsted (Feb 2011)
47 Society's response to the National Curriculum Review consultation (2011) http://www.rgs.org/NR/rdonlyres/0BD2C4C4–4DDB-4C48–831B-708F58F03C15/0/NCReviewresponseformRGSIBGresponsefinal1.pdf
48 Outdoor Science, Association for Science Education pg 5 (Jan 2011)
49 The Society would be pleased to carry out such research if modest funds to do so were available.
50 Outdoor Science, Association for Science Education pg 13 (Jan 2011)
51 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)

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.

*Dr Rita Gardner CBE*
Director
Royal Geographical Society (with IBG)

*11 May 2011*

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**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[52].

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[53].

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[54]. CaSE received no adequate response to this analysis, and is concerned that the department is ignoring the science and engineering community's concerns[55].

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[56]. 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 Key Stages 3 and 4 in inner-city schools[57]. 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"[58]. 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[59]. A practical understanding of computer science should form a more central part of the pupil experience in schools.

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[52] *Building for Growth: business priorities for education and skills*, CBI, May 2011
[53] *Science, Engineering & the Devolved Nations*, CaSE, April 2011
[54] *Letter to Michael Gove—Education*, CaSE (published online), February 2011.
[55] *Businesses concerned by school leavers' skills*, the Financial Times, May 2011
[56] *Full A-level results briefing,* JCQ, 2010.
[57] *Outdoor Science*, the Association for Science Education "Outdoor Science Working Group", 2011
[58] *The Collapse of Computing Education in English Schools*, CaSE Blog, 2011
[59] *The Importance of ICT*, Ofsted, 2009

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*

**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[60] 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-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[61] identifying that the number of associate scientific and technical professionals is set to rise by 6.5% between 2007 and 2017.

[60] Appendix 1 List of Science Council Member Organisations
[61] UKCES (2009) Working Futures 2007–17

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."[62]

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.[63] Research studies[64,65] 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.

### 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[66] and offer CPD courses. The Society for General Microbiology[67] 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[68] 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[69] provides evidence of increased enjoyment and aspirations to become a scientist or engineer.

As a former member of SCORE[70] 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

*11 May 2011*

## 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

62 NESTA 2005 Real Science http://www.nesta.org.uk/publications/assets/features/real_science
63 SCORE 2010 Practical Work in Science http://www.score-education.org/policy/wider-learning-experience/practical-work-in-science
64 Edgar, Nelson Important but not for me 2005
65 Public Attitudes to Science, Ipsos Mori, Dept. for Business, Innovation & Skills 2011
66 www.practicalphysics.org, www.practicalchemistry.org, www.practicalbiology.org
67 http://www.microbiologyonline.org.uk/teachers/safety-information,
68 http://www.thebigbangfair.co.uk/_db/_documents/The_Big_Bang_2010_Evaluation_Summary.pdf
69 After-school Science and Engineering Clubs Evaluation, DCSF Oct 2008
70 Association for Science Education, Institute of Physics, Royal Society, Royal Society of Chemistry, Society of Biology http://www.score-education.org

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 1,000 schools during the International Year of Astronomy in 2009. Simple equipment such as a pair of binoculars or one of these 1,000 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 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 5,000 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.

### 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."

*Dr Penny Fidler*
Chief Executive
The UK Association for Science and Discovery Centres

*13 May 2011*

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## 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.

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.

*Insurance Cover*

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.

4.14 Insurers like Ecclesiastical and RSA are also heavily involved in other educational sectors like independent schools and academies.

*Claims Handling*

4.15 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*

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**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 three 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 harassed 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 seven days when the class continued to use the resource in the three 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.

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