Report on the 2-year Pilot

and

10-year National Rollout

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An internal report of the Earth Science Education Unit

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The Earth Science Education Unit

Report on the 2-year Pilot and 10-year National Rollout

1. Introduction

This report analyses the success of the Earth Science Education Unit (ESEU) in delivering effective short course Professional Development (PD) across the UK over ten years. 'Success' and 'effectiveness' are considered in light of the following:

- the research carried out before the ESEU was instigated, to demonstrate to ESEU's industrial sponsor, the importance of an intervention to support Earth science education in the UK, together with subsequent research that also supported the necessity of such an intervention;
- the initial development of the Unit on the basis of an industry/education partnership of three partners, United Kingdom Offshore Operations Association (UKOOA, subsequently 'Oil and Gas UK') providing sponsorship and a business perspective, Keele University providing infrastructure and the Earth Science Teachers' Association (ESTA) providing teaching materials;
- the evolution of the ESEU from the pilot where three facilitators provided workshops to secondary schools across parts of England, to the current position of the provision of workshops to primary and secondary school and teacher training institutions across the UK, through a network of 40+ trained facilitators;
- effective working practices over the ten years following the pilot to roll the ESEU approach out nationally whilst increasing its repertoire and responding to national imperatives such as curriculum changes;
- the current work of the ESEU presenting workshops to more than half the secondary science Teacher Education institutions in the UK;
- the on-going research being carried out to maintain quality and assess impact;
- the demonstration of impact on teaching in the schools visited in 2003/4 and 2007/8;
- the fact that the ESEU approach may be unique – no anecdotal evidence or evidence from the literature has been found to indicate that there are other interventions across the world providing free-of-charge mainstream curriculum-based professional development workshops to schools and Teacher Education institutions by an industry/education partnership on a consistent basis;
- spin off initiatives, such as the '*Teaching in an Earth Context' 'Creative Science'* workshops, the '*Earth Physics'* workshops, and the international *'Earthlearningidea'* web-based initiative.

2. The Research-based Case for an Intervention to Support Earth Science Education

Prior to the instigation of the Earth Science Education Unit, a survey of 164 science teachers teaching the Earth science component of the National Curriculum for Science (NSC) in England and Wales had shown the following (King, 2001):

- 96% of the teachers were specialists in chemistry (43%), biology (27%) or physics (26%) with only one percent having a specialism in geology;
- 63% had received no education at all in Earth science through school or University whilst only 17% had received any degree-level education in Earth science;
- the amount of practical work they used in their teaching was low, investigational work even lower, whilst 80% carried out no fieldwork at all;
- the main element of support utilised was science textbooks written for pupils; including those for 11- to 14-year-olds (25% of responses), those for 14- to 16-year-olds (15%) and general science textbooks (29% of respondents); specialist Earth science teaching materials were little used;
- the second most prominent element of support was their science-teaching colleagues;
- the amount of professional development undertaken in Earth science teaching was very low;
- many of the teachers surveyed (49% 1 and 2 on a 1-5 Likert scale) were interested in obtaining more support for their Earth science teaching.

The King (2001) survey report of a high level of use of science textbooks by teachers was corroborated by a general survey of 576 secondary (high school) science teachers in England by the government Council for Science and Technology (CST, 2000) which found that 89% of the teachers surveyed used science textbooks "often". The CST survey (2000) also supported the King (2001) findings of science teachers relying on colleagues for support, by reporting that 39% used their colleagues for support "often".

The King (2001) survey reported that only 5% of the teachers of Earth science surveyed had used materials published by government departments. This low figure was again supported by the CST survey (2000) which found that only 1% of the general science teachers surveyed used materials produced by government agencies "frequently", together with "frequent" use of material published by industry of 4%, of material produced by societies of 8%, of material produced by charities of 1% and of museum-produced material of 2%.

Work carried out on the Earth science content of science textbooks in the UK prior to the instigation of the ESEU, showed that the quality was, 'variable with some containing errors, omissions and poorly presented content (Fisher 1992a, Arthur, 1996, King, 2000)' (King, 2001, p 651). This work was followed up by a survey of all science textbooks in print being used in schools in England/Wales (King et al, 2002, 2005; King, 2010) which found poor coverage of the Earth science (NSC) component, and a mean Earth science error/misconception level of one per page.

An evaluation of the quality of the Earth science component of National Curriculum for Science assessment through GCSE science examinations (for 16 year olds), showed that the science syllabuses being used in 1998 contained a mean of 2.6 errors/oversimplifications per syllabus, whilst the related examination papers showed a mean inaccuracy level of 10% of the Earth science-related questions (King et al, 1988, 1999).

An assessment of the knowledge and understanding of science teachers was carried out, prior to a workshop about plate tectonics they were attending, where it was found that 75% of the answers contained errors and 44% contained two or more errors and showed significant misconceptions (King, 2000).

These pre-ESEU research findings, together with the post-ESEU back-up research, allowed King to develop the following recommendations, which underpinned the Earth Science Education Unit development strategy:

'• Deliver the INSET [In-Service Education and Training, later called professional development] in a 'workshop' situation in which the participants work in groups and play key roles (see Appleton, 1995 and Dillon et al, 2000);
- Focus workshops clearly on the relevant statements from the NCS and make sure that these are properly understood;
- Ensure that for UK science teachers there are practical elements, since they are familiar with laboratory practical work (see Fisher, 1996, p359 and Dillon et al, 2000);
- Employ a spectrum of types of practical work (appropriate types are listed by Thompson, 1999);
- Use readily available apparatus and materials for practical work, so that the activities can easily be translated into school laboratories;
- Where possible, begin workshops with the practical activities to 'break the ice' and to encourage group discussion and investigation;
- Include a range of ideas and strategies in workshops;
- Make the links between different ideas and concepts as clear as possible (see Kennedy, 1998)
- Emphasise the 'detective approach', a valuable way of investigating many Earth science problems (Fisher, 1992b, p145 and Fisher, 1993);
- Develop workshops from concepts with which the participants are familiar, such as 'the rock cycle', or 'plate tectonics';
- Where possible, adopt a 'growth of knowledge framework' by approaching a concept such as 'plate tectonics' through the historical 'detective story' by which scientists evolved the theory (see Duschl, 1990);
- Attempt to build on the biology, chemistry or physics subject knowledge of the subject specialist teachers present (see Fisher 1992b, 1996);
- Use each of the activities to reinforce current knowledge and then to extend that knowledge and understanding to higher levels;
- Give opportunities for plenary discussion during which critical issues can be dealt with and key points made including how the material can best be utilised with pupils in classrooms/ laboratories (see Kennedy, 1998 and Dillon et al, 2000);

- Provide the participants with information to take away so that they can carry out the activities and read the explanations later;
- Provide the written information in a form that is easily translated for pupils, such as those in the 'Science of the Earth' publications described by Kennett and King, 1998.' (King, 2001, p 657).

The research carried out had shown that, even though teachers were interested in receiving professional development for their Earth science teaching, few had taken the opportunity to do so (King, 2001). Thus it was unlikely that schools and science teachers would be willing to travel to, or to pay for, Earth science professional development. Therefore, an early decision was made that the workshops should be offered free-of-charge (apart from travelling expenses) and taken to schools and Teacher Education institutions. The workshops should also be of short duration and offered at dates/ times convenient to participants. Workshops would be presented to entire science departments in schools and should typically be of 90 minutes duration; the 90 minute duration represented a trade-off between the maximum amount of time participants were likely to be willing to spend on Earth science professional development and the minimum amount of contact time that would justify the costs and effort of presenting a workshop. Workshops could, however, be combined into half-day or full-day sessions. The 'short duration, free-of-charge, workshop presented on site' decision was later validated, when ESEU workshops were offered as courses through the Science Learning Centre network across England. The courses were offered as single day events and teachers were required to pay both for attendance and their own travel costs to a central venue. Almost all the events were cancelled owing to the lack of uptake.

3. Enrolling an Industry Partner – making the business case for investment

In 1999, UKOOA, the trade association representing the companies exploring and producing oil and gas in UK waters tasked Annette Thomas with investigating how the industry could best engage with and support education as part of the industry's overall reputation and awareness strategy. The then recent responses to the controversy over the disposal of the Brent Spar oil storage buoy (1995) had demonstrated to the industry the general public's lack of awareness, understanding and appreciation of the industry's activities and its contribution to society. A major campaign was initiated which focused on "special publics" including government and the media and it was decided that a strand of this activity would be to work with education. Annette's remit was, therefore, to evaluate and make recommendations on how this could be achieved.

A Reputation Education Group (REG) was established by the industry which agreed that to achieve any meaningful impact, a strategy should be adopted which focussed on: disciplines that were critical to the industry; projects capable of long term sustainable activity; and, support activities that would contribute to the pipeline of feedstock to support the industry's talent pool of the future. Given that most companies already produced their own materials, the activities should include specific career information to complement these existing efforts.

3.1. Understanding the issue

Research was undertaken by Annette into existing provision of the many organisations active in the education industry arena. The University of York Centre for Education was engaged to review existing industry materials and she contacted and met numerous organisations and bodies. On a fact finding visit to the Association of Science Education's Annual Conference she was introduced to representatives of the Earth Science Teachers Association (ESTA). It became evident that materials to support the teaching of Earth science by non-earth science specialist science teachers were already available, published by the Earth Science Teachers' Association, ESTA (see Kennett and King, 1998). Evidence from focus groups held with teachers also supported ESTA's view that much industry-developed, often 'glossy' and high-quality material was " lingering unused and unwanted" on the shelves of many Science Departments. Additional evidence from the CST (2000) reported little "frequent" usage (only 4%) of industry-produced materials by science teachers.

Annette's research resulted in the following recommendations, based on a review of primary and secondary provision:

- new initiatives by the oil/gas industry should focus on those areas of science and technology where the industry excels; this should result in a mutually beneficial situation being created

whereby the industry has an opportunity to showcase its activities whilst teachers are supported to deliver subjects that pupils often labelled “hard” or “difficult”;

- whatever projects were eventually agreed, they should adhere to the following operating principles:
  - they must be aligned to the curriculum and so not be additional to it, since the curriculum is already crowded and teachers are under pressure to meet defined targets;
  - materials need to be easily incorporated into teachers’ schemes of work and not require additional work;
  - anything designed should not be seen as advertising by teachers, who don’t want to see one company or industry attempting to sell itself over another;
  - any initiative should be a genuine partnership which recognises the strengths, experience and professionalism of both parties, industry and education, and not as was reported by some educationalists as their experience of “industry telling education what it should do”.

3.2. Outcomes of the research into the issue

It was agreed to support the development and delivery of a suite of short earth science workshops which would be delivered to teachers in schools. The workshops would be based on Initial Teacher Education workshops previously run for trainee teachers at Keele University which were activity-based, stressed the importance of enquiry in science, addressed pedagogical issues as well as subject content and could be based on materials and strategies already developed by ESTA.

The expected outcomes were as follows.

For teachers (Lydon and King, 2009, p70) the workshops and follow-up materials would:

- increase their knowledge and understanding of earth science;
- increase their knowledge and understanding of the pedagogy of teaching earth science;
- stress the value of practical approaches to the teaching of earth science;
- provide new teaching ideas which could be used in the classroom the following day;
- increase teacher confidence in, and enthusiasm for, teaching earth science;
- develop their critical thinking skills.

For the oil and gas industry that:

- parents would see the work children were doing and how it related to oil and gas;
- pupils would be inspired by the way subjects were presented and be encouraged to continue to study them;
- real life contexts would bring subjects alive;
- by having more young people taking science subjects, ultimately the talent pool from which the industry recruits and sustains itself would increase.

4. Formation and Development of the Earth Science Education Unit

4.1. The ESEU pilot

The ESEU pilot programme was established as an industry/education partnership in which UKOOA provided the funding and the business perspective, Keele University provided the infrastructure and ESTA provided the teaching materials. An ESEU Steering Committee was developed to oversee the ESEU activities, and to provide reports to UKOOA and ESTA and two ‘workshop providers’ were appointed to ESEU for two days per week; Peter Kennett, a recently retired science/geology teacher, and Anna Hrycyszyn, a seconded practising geology teacher. This allowed ESEU to present workshops free-of-charge (apart from travelling expenses) to secondary schools and Initial Teacher Education (ITE) institutions in the Yorkshire area (Peter), the North West England area (Chris King) and the English Midlands (Anna). This approach was successful in providing workshops, as seen in Figures 1 – 3 (page 8), with 47 workshops being presented in 1999/2000 and 54 in 2000/2001, returning very good evaluation scores and anecdotal feedback. However, the approach was less successful in that it was relatively expensive (cost of two 2-days per week salaries) inflexible (Anna could only provide workshops on her seconded days, Thursdays and Fridays, when many people in the Midlands wanted them on other days), and impractical for extending to other regions. Since ESEU then moved on to the different working model, described overleaf, the first two years (1999-2001) were retrospectively called ‘the ESEU pilot’.

4.2. The ESEU UK rollout (England and Wales, 2002 – 2006) and consolidation (2007 – 2011)

It was during the industry/education partnership review of the ESEU Pilot Programme, which was a precursor for bidding for further funding, that the business perspective became crucial. Using criteria and concepts such as resource utilisation and mobilisation costs, it became clear that employing workshop providers on a part-time basis would not be a cost effective model if ESEU activities were to be rolled out across the UK. Thus a different model was developed, which was based on a network of peripatetic facilitators based in locations across the country who could be employed *ad hoc* to run individual workshops in their areas. This model was much more flexible and efficient, since providers would only be paid for the workshops they presented and not for non-productive downtime, plus the travel costs would be minimised. For these reasons, a new model was developed which consisted of:

- a full-time Central Team member employed at Keele University to coordinate all activities including marketing, liaising with schools wishing to book workshops, liaising with workshop providers, arranging payments and administering all activities;
- a part-time Director, overseeing the ESEU initiative (King);
- a Steering Committee to guide ESEU progress;
- workshop providers with suitable Earth science qualifications, henceforward called facilitators, were advertised for, selected by interview, trained, provided with a 'kit' of apparatus and materials and then asked to provide workshops in their own regions;
- a progressive rollout from the original three regions of England, to six regions and Wales, then to all nine English regions, Scotland and Northern Ireland;
- this required five years of funding, from 2002 to 2006 (at a time when the prevailing funding model in the oil industry was for one year projects only).

The bid for funding to UKOOA, based on this model, was accepted and the rollout programme began.

4.3. The successful rollout model

The success of the ESEU provision is indicated by the increasing numbers of workshop bookings and the maintenance of evaluation levels, as the facilitator network was developed, together with the evidence of impact.

Research was undertaken to evaluate the impact of ESEU workshops in schools visited during 2003/4, and found that Schemes of Work had been altered in every school which responded to the survey (33% of the schools visited). This finding, together with the good track record of workshop provision, was crucial to the success of the bid for a further five years' worth of funding from UKOOA, which was granted for 2007 – 2011. More details of the research are given later in this report.

The progress of the five-year national rollout across England and Wales, together with the further five years of consolidation can be seen in Figures 1 – 3 overleaf.

Figure 1. The numbers of ESEU visits to secondary science teachers in schools and other venues and to secondary science trainees in ITE institutions, 1999 – 2011.

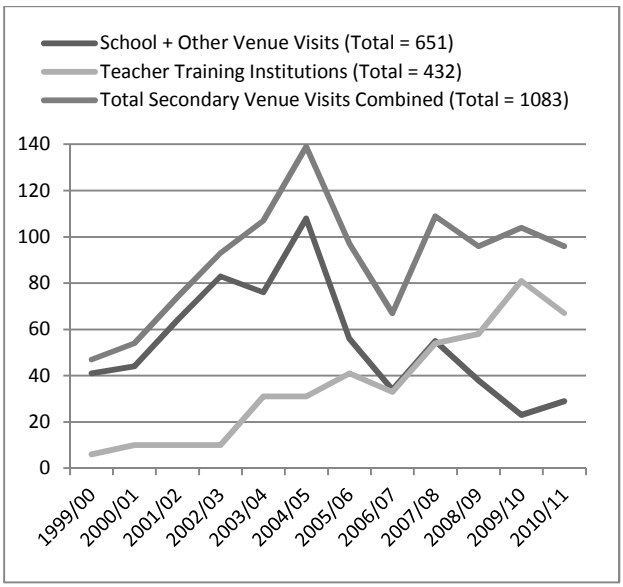


Figure 2. The numbers of individual secondary science teachers and secondary science trainees who received ESEU workshops, 1999 – 2011.

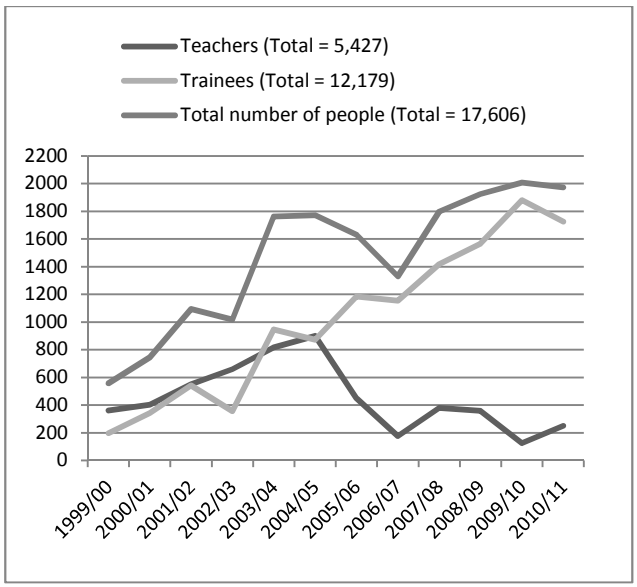
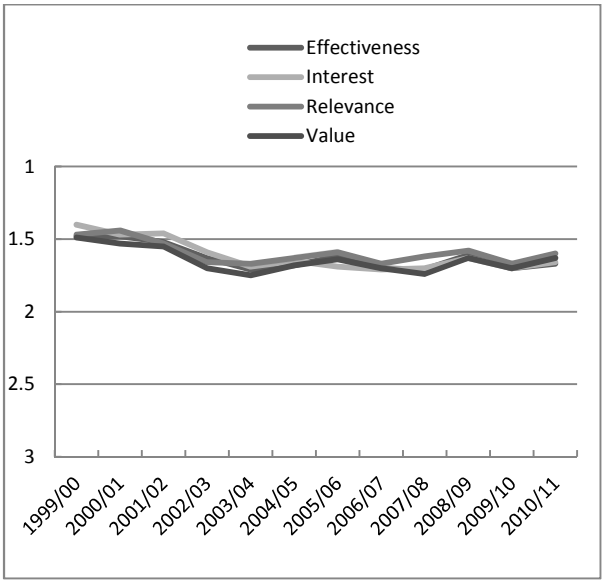


Figure 3. Mean evaluation scores for ESEU secondary Earth science workshops, 1999 – 2011 (Likert scale 1 – 5, with 1 being high).



The figures show a fairly steady rise in the numbers of ITE workshops and individuals (with a drop in 2006/7), but a general decline in school bookings from the early 2000s. Meanwhile the mean evaluation scores which had initially dropped a little (from around 1.5 to around 1.7) plateaued at relatively high values.

The reasons for the 2006/7 dip maybe because of a change in ESEU administration at that stage, although changes in secondary schools/ITE institutions or externally-driven curriculum changes (such as the introduction of new GCSEs) cannot be ruled out. The steady drop in school bookings in recent years probably reflects the fact that all the 'easy targets' were hit during the early ESEU work,

together with increasing pressures on schools, resulting in less time/energy being available for professional development. The contrast with ITE institutions occurs because annual repeat bookings, which train new groups of trainee teachers year by year, are possible with ITE institutions, whilst most schools only make one booking. The mere fact that repeat ITE bookings are the norm for ESEU indicates that the ESEU approach is meeting a real need in teacher education.

The figures show that ESEU visited ITE teacher training institutions 67 times in 2010/2011. Meanwhile unpublished research carried out for the Wellcome Trust (Lock et al, 2011a, p16) found during a survey of tutors of secondary science ITE institutions in England, that 46% of them had their earth science input provided by visiting speakers. Since ESEU is the only organisation in the UK providing such a service and since, in addition to this, ESEU workshops were provided by ESEU facilitators at two ITE institutions by internal speakers, this research shows independently that ESEU provided workshops to trainee science teachers at more than half the ITE institutions in England during 2010/11. This was corroborated by the documentation study part of the Lock et al research into the programmes offered by secondary science ITE institutions (2011b, p18).

4.4. ESEU in Scotland, 2003 – 2011

ESEU's work in Scotland began in 2003 in the same way that all new ESEU workshops initiatives have begun (following identification of suitable funding) by running a developmental 'writing workshop', as described in the section below. In the case of the ESEU Scottish writing workshop, existing ESEU facilitators, members of the Scottish Earth Science Education Forum (SESEF) and primary teachers local to the Aberdeen area (where the workshop was held) came together for two days, and produced between them the materials for two upper primary (elementary) workshops (for teachers of 9 – 11 year old pupils).). The workshops focussed on upper primary education because, unlike in England and Wales, the main Earth science input to the science curriculum in Scotland was to the upper primary age group and was much less at secondary level. The workshops developed were then piloted in schools in the Aberdeen area, revised in the light of the pilot, and prepared for launching. Meanwhile, potential facilitators in Scotland had been advertised for, interviewed, appointed and trained in workshop delivery. This allowed the workshops to be rolled out across Scotland, with the results shown in Figures 4 – 6 below and overleaf.

Figure 4. The numbers of ESEU visits to primary teachers and trainees and secondary science teachers and trainees in Scotland, 2003 – 2011.

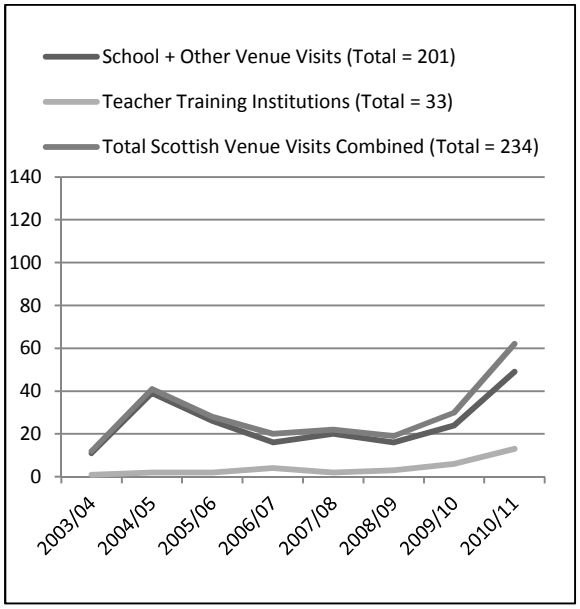


Figure 5. The numbers of individual primary teachers and trainees and secondary science teachers and trainees who received ESEU visits in Scotland, 2003 – 2011.

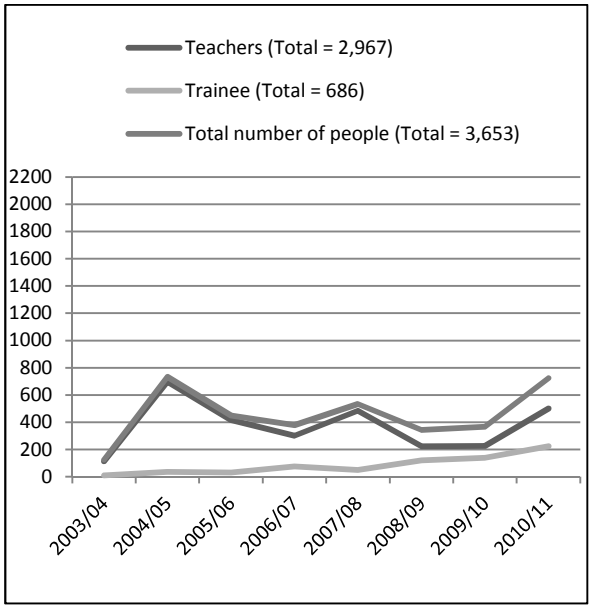
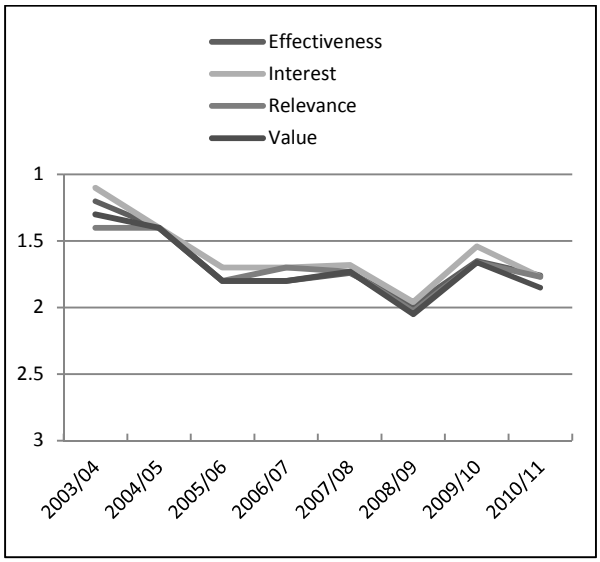


Figure 6. Mean evaluation scores for ESEU workshops presented in Scotland, 1999 – 2011
(Likert scale 1 – 5, with 1 being high).



The graphs show variability in numbers of workshops and in individuals reached year by year, probably reflecting changes in ESEU administrative staff as well as changes in school priorities. The recent encouraging increase can be attributed to the development of three new workshops aimed at the new Curriculum for Excellence in Scotland, with increased numbers of facilitators and focus for the first time, on the whole age range, from early years to secondary. It is interesting to note that evaluation results showed the same pattern in Scotland as in England, with workshops during the pilot phase producing the best evaluations, a slight drop as the workshops were rolled out through more facilitators and regions, to a fluctuating plateau at a relatively high level.

4.5. ESEU at primary level, 2008 - 2011

The bid for 2007 – 2011 funding included an element for the development and rolling out of primary ESEU workshops across England and Wales. Thus a developmental primary writing workshop was convened to develop appropriate materials. This was attended by practising ESEU facilitators, members of the Earth Science Teachers' Association (ESTA) Primary Committee, and primary teachers local to Keele University where the workshop ran. This allowed the development of three new workshops, one for teachers of lower junior pupils (7 – 9 year olds) and two for upper junior pupils (9 – 11 year olds). Following advertising, interviewing, appointing and training of ESEU primary facilitators across England and Wales, the new workshops were launched in 2008. Figures 7 – 9 (overleaf) show the progress of the ESEU primary initiative.

Figure 7. The numbers of ESEU visits to primary teachers and primary trainees in England and Wales, 2008 – 2011.

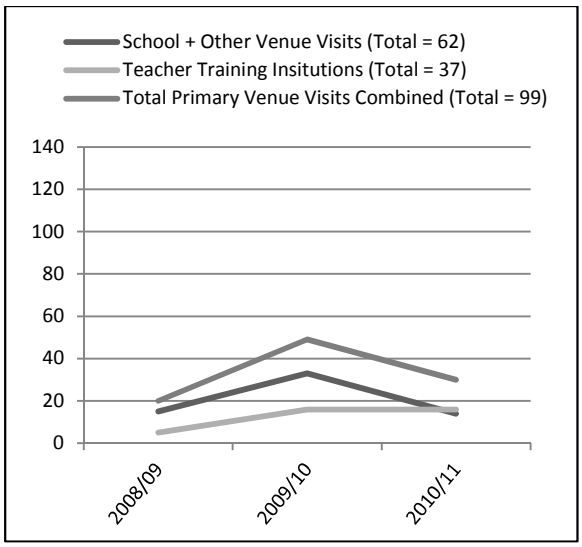


Figure 8. The numbers of individual primary teachers and primary trainees in England and Wales who received ESEU workshops, 2008 – 2011.

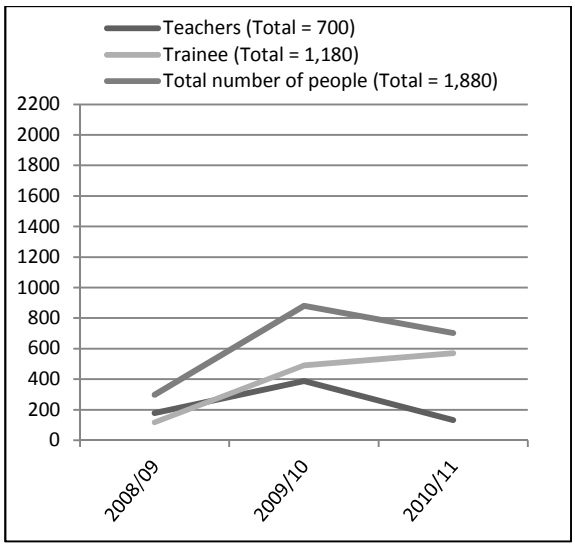
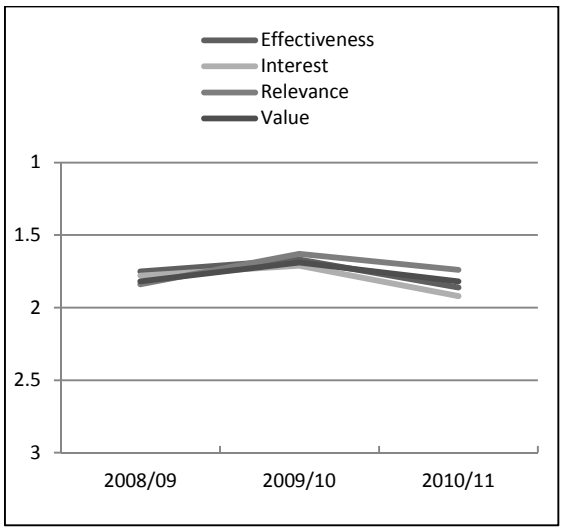


Figure 9. Mean evaluation scores for ESEU primary Earth science workshops, 2008 – 2011
(Likert scale 1 – 5, with 1 being high).



The figures show an initial growth, followed by a small decline, which again probably reflects changes in central ESEU administration, but may also reflect school priorities. Nevertheless, bookings continue at pleasing levels and the maintenance of the numbers of ITE individuals involved was good. Unlike previous workshops, no major piloting phase was undertaken, since many of the materials had previously been used in ESTA workshops, so the evaluation figures simply relate to the rollout phase, and have been maintained at steady levels.

4.6. ESEU in Northern Ireland, 2007 – 2011

Northern Ireland has a similar curriculum to that in England and Wales. Following a decision that the most effective way of presenting ESEU English/Welsh workshops in Northern Ireland would be to fly experienced facilitators from the mainland to present the workshops, ESEU secondary workshops have been presented annually in Northern Ireland since 2007/8, and ESEU primary workshops since 2008/9 – with continuing very positive evaluation feedback.

4.7. Perspectives on the ESEU initiative, 1999 – 2011

A summary of ESEU activity over the years is shown in Figures 10 and 11 and Table 1.

Figure 10. The total number of ESEU visits, 1999 – 2011.

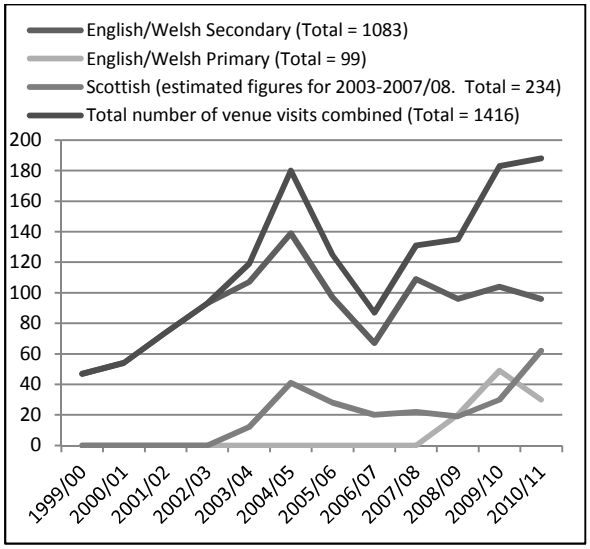


Figure 11. The total number of individual teachers and trainees who received ESEU workshops, 1999-2011.

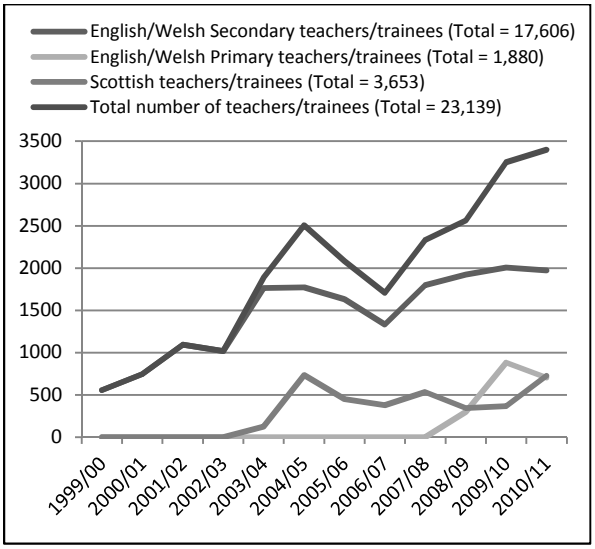


Table 1. Total numbers of visits made and the number of teachers and trainee teachers who received ESEU workshops, 1999 – 2011.

Country/age range	No. of visits		
	to schools and other venues	in teacher training institutions only	Total number of Visits
Secondary (E, NI, W) 1999-2011	651	432	1083
Primary (E, NI, W) 2008-2011	62	37	99
Scotland 2003-2011	201	33	234
Total 1999-2011	**914**	**502**	**1416**

Country/age range	No. of participants		
	in schools and other venue	in teacher training institutions only	Total number of participants
Secondary (E, NI, W) 1999-2011	5,427	12,179	17,606
Primary (E, NI, W) 2008-2011	700	1,180	1,880
Scotland 2003-2011	2,967	686	3,653
Total 1999-2011	**9,094**	**14,045**	**23,139**

It is possible to use a 'multiplier' to gauge how many pupils ESEU's work with teachers may have impacted upon. ESEU background data was collected on each secondary school visited, and the numbers of pupils in each school recorded. Data collected from the feedback evaluation forms from 2006/7 to 20010/11 show that ESEU visited 93 schools and presented workshops to 863 teachers; the total number of pupils in these schools was 339,569. Since ESEU workshops in secondary schools were presented to whole science departments, it is reasonable to assume that the ESEU input could impact on every pupil in the school. This gives a 'multiplier' effect of 339,569/863 or 393 pupils per teacher. Applying this 'multiplier' to the 5427 secondary science teachers who have received ESEU workshops since ESEU began, shows that ESEU's work in secondary schools in England, Wales and Northern Ireland may have impacted on the education of more than two million secondary pupils.

Such figures were not collected by ESEU for Scottish schools. However, the regulations in Scotland are for maximum primary (elementary) class sizes of 33 (Scottish Government Website), with many classes being smaller than this. If the mean primary class size in Scotland were 15, then the Scottish teachers who received professional development from ESEU would have influenced approaching half a million pupils per year.

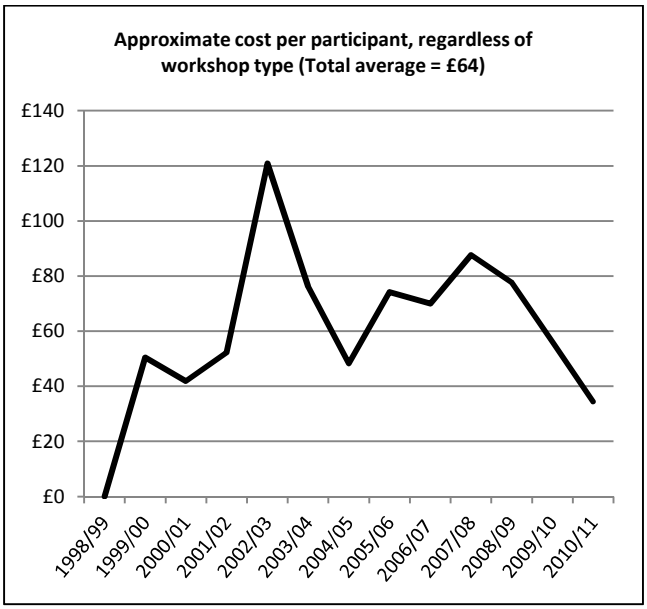
The mean class size for English primary (elementary) schools, published by the government in 2007, was 26.2 (Department for Education website). Using this figure as a 'multiplier' would indicate that the 700 primary teachers who received ESEU professional development would teach more than 18,000 pupils per year.

The number of pupils potentially influenced by the 13,359 primary and secondary trainees who have received ESEU workshops over their teaching lifetimes is incalculable, but must reach very large figures indeed.

Combined, these figures indicate that the ESEU initiative has influenced millions of pupils across the UK since its inception.

The 'cost per participant' in ESEU workshops can be calculated by dividing the number of workshops per year by the funding utilised, as shown in Figure 12.

Figure 12. ESEU cost per participant, 1999 – 2011.



The graph has fluctuated, since some years have incurred additional costs, such as workshop development or launch events. However, the mean cost per participant over all the years of ESEU activity is around £64 (about US$102 or €116).

5. ESEU Workshop Development

5.1. Development and range

ESEU developmental writing workshops are based on a format originally developed by the Earth Science Teachers' Association (ESTA) for developing new '*Science of the Earth'* teaching materials (see Kennett and King, 1998), and later utilised by the Joint Earth Science Education Initiative (JESEI) to develop new web-based Earth science teaching materials (see the JESEI website). Each writing workshop brought together Earth science educators with other specialists in order to develop new materials and, although the experience has been variable, it has generally been very successful.

Most (but not all) of the workshops have been developed to a common format around a theme, indicated by the title, and each of the activities devised was closely linked to an element of the national curriculum of the country involved. The common format usually included:

- a starter activity – to introduce the topic to participants and get them involved;
- a circus of activities (between 5 and 8) that participants trial and report back on later in the workshop;
- a plenary activity – to bring many of the elements of the workshop together in a final activity.

Each workshop is based on a booklet including all the activities with the back-up expected by teachers, such as national curriculum references, pupil learning outcomes, resource lists and model answers. The booklets and their related PowerPoints are given to each participant on a CD ROM during the workshop.

One of the lessons learned through ESEU developmental workshops, was that after the writing workshop, there was a great deal of work to be done in turning a series of sometimes disparate embryonic ideas into finished activities and workshop materials. The major ESEU workshops developed since 1999 are shown in Table 2; each workshop lasts for 90 minutes to two hours.

Table 2. The major ESEU workshops*.

Age Range	England/Wales		Scotland	
14 – 16 years	*The plate tectonic interactive*	1999	*Scotland on a plate*	2010, revised 2011
	Investigating the changing Earth and atmosphere	1999		
	The Earth and plate tectonics	2007, revised 2011		
	Life, the atmosphere and everything	2007, revised 2011		
11 – 14 years	*The dynamic rock cycle*	1999, revised 2002, 2011	*Scotland's rocky journey*	2010, revised 2011
	Spot that rock	1999, revised 2001, 2005, 2011		
9 – 11 years	*How the Earth works in your classroom*	2008, revised 2011	*Scotland's journey*	2003
			Science through the window	2003
7 – 9 years	*The rock and soil circus*	2008, revised 2011		
	Spot that rock	2008, revised 2011		
5 – 7 years			*Scotland rocks*	2010 revised 2011

* In addition, shorter ESEU workshops include: Earth science out of doors – 1999; Will your gravestone last? – 1999; Any quarry guide – 2005; Virtual rock kit – 2009.

5.2. Perspectives of participants during ESEU workshop development

During an ESEU writing workshop, modelled on the above pattern but to develop *'Creative science'* materials (more details of the ESEU *'Creative science'* work are given later), ESEU researched the writing workshop process, with the following findings.

The 22 participants were asked to give perspectives on their involvement and confidence over the two days, by recording their responses to three questions at the start of Day 1, at the end of Day 1 and at the end of Day 2, using a 1 – 5 Likert scale.

The response to, *"The objectives of the workshop are clear to me"* was that 20 people agreed (6 strongly) and two were neutral at the start of Day 1; by the end of Day 1, two people had increased, whilst one had dipped; then by the end of Day 2, 12 people agreed more strongly whilst 10 showed no overall change.

Meanwhile, the response to, *"I feel confident that I will be able to help the group meet those objectives"* was that 13 people agreed (4 strongly) and nine were neutral at the start of Day 1; by the end of Day 1, three people had increased, whilst one had dipped; by the end of Day 2, 15 people agreed more strongly whilst seven showed no overall change.

The response to, *"I feel enthusiastic about what we are doing"* was that all 22 people agreed (18 strongly) at the start of Day 1; by the end of Day 1, two had dipped; by the end of Day 2, three people agreed more strongly whilst eighteen showed no overall change

These responses show a pleasing upward trend from the start of Day 1 to the end of Day 2, with greater enthusiasm, confidence and understanding of the objectives at the end. However, they also indicate little change by the end of Day 1, suggesting that participants spent Day 1 getting to grips with the issues, but by Day 2 they were able to move forward with confidence and understanding.

Further questionnaires completed at the end of the course, using written comments, were generally very positive.

The process was also evaluated by external evaluators who commented, 'The impact on the participants was overwhelmingly positive. There were many reasons why this session buzzed …, but it appears that the key reason was that they had to think for themselves, and in the process of thinking and talking to others and then seeing if their ideas worked in practice, they became more creative than they had imagined possible. They were automatically being critical of their own ideas and the ideas of others. … "I could never have believed it possible that we could have generated so many 'new' ideas in so short a space of time." … The course was excellent.'(MMU, 2004, penultimate page).

6. ESEU Research into Workshop Impact

ESEU carried out a survey into the impact of ESEU workshops on the schools visited in 2003/4, as reported in Lydon & King (2009). The 2009 paper reviewed the different elements necessary in professional development to ensure that it had impact, and highlighted in particular the four component strategy of Joyce & Showers (1988), later developed by Harland & Kinder (1997) into a nine component model; the seven component method of Day (1999) taken from Steadman et al, (1995); the four principles advocated by Guskey (2000); and the 14 factors listed by Adey (2004).

Guskey (2000) developed his four principles approach into a five component framework for evaluating professional development and Muijs et al (2004) added a level of evaluation preceding Guskey's five stages, focussing on conditions prior to a professional development episode. It was this six stage framework that was used, as far as was practicable, for assessing the impact of the ESEU workshops presented to schools in 2003/4. The 2003/4 survey was replicated by ESEU for schools visited in 2007/8, using the same methodology.

The Guskey/Muijs approach used the following framework:
1. conditions prior to CPD (Continuing Professional Development);
2. participant reactions;
3. participant learning;
4. organisational support and change;
5. participants' use of new knowledge and skills;
6. student learning outcomes.

The ESEU research is presented under these headings below, apart from the last, since ESEU had no capacity to work with schools to evaluate student learning outcomes. Meanwhile establishing causal links between a single short workshop and changes in pupil outcomes would be very problematical anyway.

6.1. Conditions prior to CPD – baseline questionnaire data

It is normal ESEU practice to ask each participating secondary (high school) science department to complete a 'baseline questionnaire' prior to the workshop, providing details of school demographics and levels of Earth science teaching (number of hours per year group, and levels of practical, investigational and outdoor teaching) in their school. In 2003/4, of the 46 schools visited that year, 31 schools responded. The data provided showed that the schools ranged in size from 350 to 2200 pupils (mean of 1221) and between 4 and 20 science teaching staff (mean 11). In the 2007/8 survey, of the 32 schools visited, 10 schools responded, these ranged in size from 600 to 2000 (mean 1101) with between 5 and 20 science staff (mean 11).

Table 3 shows the levels of Earth science teaching in the schools covered by each survey, whilst Table 4 shows the amounts of practical, investigational and outdoor fieldwork included in the teaching.

Table 3. Hours of earth science teaching reported in schools visited, prior to ESEU workshop.
2003/4 survey data from Lydon & King (2009).

Academic year of survey (n = No. schools included)	**Total hours of Earth science teaching**	**Minimum**	**Maximum**	**Mean**
2003/4 (n = 31)	Key Stage 3 (11 – 14 year olds)	4	25	16
	Key Stage 4 (14 – 16 year olds)	4	40	13
2007/8 (n = 10)	Key Stage 3 (11 – 14 year olds)	12	33	20
	Key Stage 4 (14 – 16 year olds)	0	18	5

Table 4 Amount of practical, investigational and fieldwork reported in schools visited, prior to ESEU workshop. 2003/4 survey data from Lydon & King (2009).

Academic year of survey (n = No. schools included)	**Levels of different modes of Earth science teaching**		**Likert scale[a]**					**None**	**Don't know**	**No response**
			1	2	3	4	5			
2003/4 (n = 31)	Amount of practical work …	… included in Earth science teaching across the school	3	0	42	42	6	0	0	6
	Amount of Sc1 investigational work …		0	0	6	19	55	13	3	3
	Amount of field work …		0	0	3	13	45	35	0	3
2007/8 (n = 10)	Amount of practical work …	… included in Earth science teaching across the school	0	30	40	20	10	0	0	0
	Amount of Sc1 investigational work …		0	0	30	20	20	10	10	10
	Amount of field work …		0	0	0	20	40	40	0	0

Note: [a] 1 = high, 5 = low.

The differences in the amount of earth science reportedly taught between the 2003/4 and 2007/8 surveys may be the result of the smaller number of schools that provided data for the 2007/8 survey. However, they may also reflect that:

- at Key Stage 3 (11 – 14 year olds), understanding of the earth science and amount of earth science that needed to be taught for the National Curriculum was settling down, with the minimum amount of earth science teaching necessary being more clearly understood;
- at Key Stage 4 (14 – 16 year olds), the amount of earth science teaching depends upon the GCSE science examination specification taught, with some containing more earth science than others.

The figures in Table 3 indicate a small increase in the amount of both practical and investigational work included in Earth science teaching. However, the amount of field work continued to be very low, with many schools doing no fieldwork at all.

Together the two sets of data show that the surprising variation in the amount of Earth science taught in science lessons in schools remains, despite the fact that the schools are following the same statutory National Curriculum requirements. They also show that the practical and investigational work carried out in earth science lessons remains low (when elsewhere in UK science teaching, practical work is common), with fieldwork remaining particularly low.

6.2. Participant reactions – participant evaluation data

Following each ESEU workshop, participants were asked to evaluate the workshop on a five-point Likert scale in terms of its effectiveness, interest, relevance and value.

The results from the two surveys are shown in Table 5 overleaf.

Table 5. Teacher participant reactions to workshops, 2003/4 and 2007/8.

Participant reactions, as a percentage of all responses							
Year of survey	**Evaluation measure**	**Likert scale[a]**					**No response**
		1	**2**	**3**	**4**	**5**	
2003/4 survey (n = 274)	I found the effectiveness of the INSET to be	55	36	5	1	0	1
	The interest of the INSET was	59	33	7	1	0	0
	The relevance of the INSET was	55	35	9	1	0	0
	The value of the INSET to me was	53	35	8	3	0	0
2007/8 survey (n = 199)	I found the effectiveness of the INSET to be	53	40	6	1	0	0
	The interest of the INSET was	59	34	6	1	0	0
	The relevance of the INSET was	58	33	8	1	0	0
	The value of the INSET to me was	53	35	11	1	0	0

The participant reactions are remarkably similar in the survey data from both years, indicating that the, 'positive CPD experience conducive to positive higher level outcomes.' (Lydon & King, 2009, p72) has continued.

6.3. Participant learning – participant evaluation data

Participant learning through ESEU workshops was also assessed by participant questionnaires, through questions that can be related to Guskey's (2000) three types of learning goal:

- cognitive goals - questions 2 and 3 in Table 6, below;
- psychomotor skills – questions 4, 5 and 6;
- affective goals – question 1.

The results for the 2003/4 survey and the 2007/8 survey are given in Table 6 below.

Table 6: Self-reported participant learning 2003/2004 and 2007/8.

Self-reported participant learning, as a percentage of all responses								
Year of survey	**Evaluation measure**	**Likert scale 1= strongly agree, 5 = strongly disagree**					**Not applicable**	**No response**
		1	**2**	**3**	**4**	**5**		
2003/4 survey (n = 274)	1. The workshop has improved my confidence in teaching Earth science	33	43	17	2	0	1	4
	2. The workshop has improved my Earth science knowledge and understanding	34	29	8	2	0	0	26
	3. The workshop has given me new ideas for ways of teaching Earth science	38	26	5	0	0	1	30
	4. The workshop will increase the amount of Earth science practical work I teach	46	38	10	1	0	1	3
	5. The workshop will increase the amount of Earth science investigational work I teach	26	34	28	5	1	1	5
	6. The workshop will increase the total amount of Earth science I teach	12	27	35	8	6	5	7
2007/8 survey (n = 199)	1. The workshop has improved my confidence in teaching Earth science	33	46	16	1	0	1	0
	2. The workshop has improved my Earth science knowledge and understanding	47	34	12	5	1	1	0
	3. The workshop has given me new ideas for ways of teaching Earth science	57	32	6	0	1	2	2
	4. The workshop will increase the amount of Earth science practical work I teach	46	39	10	2	0	1	2
	5. The workshop will increase the amount of Earth science investigational work I teach	26	37	26	4	2	2	3
	6. The workshop will increase the total amount of Earth science I teach	14	31	33	7	7	3	5

The data for participant learning in 2007/8 is very similar to that for 2003/4, but in 2007/8 the positive feedback about both Earth science knowledge and understanding, and new ideas for teaching Earth science, was even more positive, whilst more participants responded to both these points.

6.4. Organisational support and change – post-workshop follow-up data

The post-workshop follow-up data, to establish the impact of the workshops on the schools where they were presented, was collected by postal questionnaire in the 2003/4 survey and by an on-line questionnaire (using Surveymonkey™) for the 2007/8 data. Both surveys were conducted a year after the workshop had been delivered, to give time for the school to work through its annual curriculum and for changes to be incorporated into their Earth science teaching. The 2003/4 and 2007/8 survey questionnaires asked the same questions.

In 2003/4, 15 of the 46 schools visited responded (a 33% response rate) whilst in 2007/8 ten of the 32 schools visited responded (31% response rate). The schools in 2003/4 were mainly comprehensive schools (with one selective school) whilst the 2007/8 schools showed a similar mix, being mainly comprehensive with one selective and one independent ('public') school.

As a guide to the impact of ESEU workshops on the 'organisational support and change' in the schools visited in 2003/4, the survey sought data on the school's Scheme of Work, by asking, *'Have changes been made to your school's Scheme of Work as a result of the session?'*. The results were reported as follows, 'Thirteen out of the 15 schools reported that they had made changes to the relevant scheme of work as a result of participation in a workshop. One of the remaining schools reported that changes were being planned, and the other school relied on pre-existing standard government schemes (provided by the Qualifications and Curriculum Authority) rather than preparing its own.' (Lydon & King, 2009, p78) and, 'Effectively all schools had modified their scheme of work, showing that ESEU activities and approaches had been incorporated into their teaching programmes on a long term basis.' (ibid, p80)

The response to the similar question in the 2007/8 survey was that, of the ten questionnaires returned, one school made no comment; one school responded that their Schemes of Work were pre-published and one indicated that the workshop material was not closely relevant to their particular curriculum. The remaining schools indicated that they had changed their Scheme of Work. These responses give a slightly poorer perspective than the 2003/4 survey, so the summary sentence above could be changed to, 'The majority of schools had modified their scheme of work, showing that ESEU activities and approaches had been incorporated into their teaching programmes on a long term basis.'

6.5. Participants' use of new knowledge and skills – post-workshop follow-up data

The methodology used to determine the impact of the workshop on the participants' use of new knowledge and skills in schools is described in Lydon & King (2009), but briefly involves a measure of how much the use of activity was increased using a code of A (major increase) to D (no increase), calculating the percentage of each of the workshop activities in each category (given in Table 7) and then using this to allocate an appropriate term for the impact of the workshop (No change (Category D only) = 'None'; Change limited to Category C = 'Modest'; Some change in Category B = 'Moderate'; and Some change in Category A = 'Significant'). Note the proviso also given, 'The degree to which activities are already in use prior to the workshop limits the potential impact, since only if some categories are novel for all teachers will it be possible to bring about a category A change…' (Lydon & King, 2009, p77).

Table 7 below summarises the results of this part of the survey in Lydon & King (2009). Meanwhile, Table 8 overleaf, provides the full data for the 2007/8 survey.

Table 7 Percentage of the activities that fall into each category of use increase, for each school (2003/4 survey).

	Rock Cycle workshop (aimed at 11-14 year olds) (9 activities)		**Plate Tectonics workshop (aimed at 14-16 year olds) (9 activities)**	
Total	**Modest**	**3**	**Modest**	**2**
	Moderate	**2**	**Moderate**	**1**
	Significant	**5**	**Significant**	**0**

Table 8 Percentage of the activities that fall into each category of use increase, for each school (2007/8 survey).

School	Rock Cycle workshop (aimed at 11-14 year olds) (9 activities)					Plate Tectonics workshop (aimed at 14-16 year olds) (9 activities)				
	%A	%B	%C	%D	Summary	%A	%B	%C	%D	Summary
1	11	0	44	44	Moderate	0	11	33	56	Moderate
2						0	11	56	33	Moderate
4	0	0	100	0	Modest					
5	0	0	33	67	Modest	0	0	56	44	Modest
6	0	0	22	78	Modest	0	0	11	89	Modest
7	0	0	89	11	Modest					
9						0	11	56	33	Moderate
10	0	0	56	44	Modest	0	0	33	67	Modest
Total	Modest		5			Modest		3		
	Moderate		1			Moderate		3		
	Significant		0			Significant		0		

* Notes: Schools with no results shown did not respond to this part of the survey. No feedback data was collected for other ESEU workshops presented.

6.6. Comparisons between the 2003/4 and the 2007/8 surveys

These indicate the following:

- all schools in both surveys reported at least a modest change;
- in the 2003/4 survey, half the Rock Cycle workshops resulted in 'Significant' change, whereas the overall change caused by the Rock Cycle workshop in the 2007/8 survey was lower;
- the limited data on the Plate Tectonics workshop in the 2003/4 survey showed fairly minor change, whilst the impact of this workshop in the 2007/8 survey was greater;
- the 2003/4 survey comments included, 'Activities were rarely already in use by teachers' (ibid, p77); this was not the case in the 2007/8 survey, where some of the activities were in use by every school. This difference causes the comparisons between the two surveys to be less valid, since the results of the 2007/8 survey could not reach such high levels for this reason.

6.7. Discussion of Research into the impact of ESEU Interventions

The findings of the ESEU 2003/4 survey (reported in Lydon & King, 2009) and the 2007/8 survey were very similar – giving additional weight to the conclusions discussed below. Given the smaller number of schools that took part in the later survey, the differences may not be very significant, however, contrasts noted were:

- schools seemed to gaining a clearer idea of the number of hours of Earth science necessary to fulfil the curriculum requirements;
- the amount of practical/investigative Earth science teaching was showing an increase;
- the amount of fieldwork remained very low, with many schools doing no fieldwork;
- the impact of the workshops, as measured by changes in Schemes of Work, was slightly less in the later survey;
- in the later survey, the impact of the rock cycle workshop was less, but that of the plate tectonic workshop was greater.

The reason for the increase in amount of practical/investigational work and the reduction in impact of the rock cycle workshop may both reflect the national work of the ESEU, in currently presenting workshops at more than half the secondary science teacher training institutions in the country. If the new teachers employed by schools have received ESEU training, they may bring ESEU practical approaches with them that would both increase the amount of practical work being done, but would reduce the potential impact of an ESEU workshop, which records 'significant impact' only if some teachers were not familiar with any of the practical activities before the workshop.

As noted in the report on the 2003/4 survey, there are sources of potential bias in the research, which also apply to the 2007/8 survey. The schools involved were self-selecting on two levels, by having first requested an ESEU workshop, and then by being willing to provide the additional data outlined above. Therefore, the schools may represent institutions that are more open to science professional development in general; those that have recognised the need for support for their Earth science

teaching; those schools in which the ESEU workshop had the most impact; or a combination of these factors.

The 2009 Lydon & King Report concluded by revisiting the perspective of published researchers that, in order to be effective, CPD required a range of elements, from the four components of Joyce & Showers (1988) to the 14 factors of Adey (2004) – and that all factors have to be present for success; and they have to be sustained, sequential and cumulative. Furthermore, it noted the researchers' contention that, 'final phases of 'opportunities for experiment/practice' (Day 1999; Adey, 2004, Cordingley et al, 2005) and of 'coaching' (by peers or advisory teachers; Joyce & Showers, 1988; Day, 1999, Adey, 2004, Cordingley et al, 2005) are essential for changing student learning.' (Lydon & King, 2009, p79). Although these views were disputed to a degree by Harland & Kinder (1997) who argued that some impact could be achieved if not all factors were present - all these researchers contended that, to be effective, professional development had to be long-term and comprehensive.

The ESEU impact research of the 2003/4 and 2007/8 surveys, counters these views. Despite the ESEU workshops being short (90 minutes) and not offering opportunities for practice or coaching, the outcomes, when evaluated against the Guskey (2000)/Muijs et al (2004) model, were positive, with nearly all schools that responded to the research reporting long term changes on varying scales.

Despite being 'short' many of the elements described by researchers as 'essential' are present in ESEU workshops, including eight of the 14 factors identified by Adey (2004). Additional factors that may have caused the impact of ESEU workshops and identified in the Lydon & King (2009) Report include:

- the importance of the workshops being presented to whole science departments, so that further discussion and support could be provided by colleagues after the workshop;
- the fact that ESEU presenters have extensive expertise in their own subject area as well as being well trained in the presentation and pedagogy of the workshops.

The Lydon & King (2009) Report concluded the following and this conclusion remains apt following the 2007/8 replication of the 2003/4 research.

> 'The demonstrated success of the ESEU model of short, single workshops in bringing about lasting change in practice is noteworthy, given the emphasis in the literature that CPD [professional development] can only be effective if it is sustained. Interestingly, in his dismissal of the short CPD episode, Adey offered a case for exception:
>
> "There is universal condemnation in the research literature on professional development for the one-shot 'INSET day' as a method of bringing about any real change in teaching practice. Perhaps the only exception to this rule is the introduction of a very specific technical skill, such as the use of new piece of software." (Adey, 2004, p.161)
>
> The evidence described above indicates that this exception should be extended to include the transmission of practical science teaching ideas (and fostering of skills and confidence in using them, with the associated building of knowledge and understanding), where training is delivered by a well-trained provider, within a well-structured workshop which provides opportunities for exploration, practice, and peer feedback.' (Lydon & King, 2009, p81).

Similar, although not so extensively researched, findings have also been found for short course professional development in practical Earth science teaching in Portugal (Rebelo et al, 2003) and Germany (Hansen & Hlawatsc, 2006).

Since publication of the 2003/4 survey results, research into the impact of professional development has continued apace. Hunzicker (2011) offered a checklist of features that make professional development effective whilst, Bennett et al (2010) have developed a classroom impact route model. Desimone (2009) has argued for a common conceptual framework for assessing the impact of all professional development whilst Hanley et al (2008) presented a four-feature process-focussed model of evaluation. Kennedy (2005) identified nine different models of professional development and suggested a framework appropriate for analysing them.

Meanwhile Penuel et al (2007) in an extensive evaluation, showed findings consistent with previous researchers, that coherent professional development experiences were essential for impact whilst Jeanpierre et al (2005) highlighted a range of factors necessary for success.

Research into the impact of professional development in Earth science by Constible et al (2007), Clark & Carpenter (2006) and Penuel (2005) all highlighted successful programmes.

However, these studies all have in common the fact that they focussed on long-duration professional development courses, rather than the short workshop approach utilised by ESEU. Reports on the effectiveness of short-course professional development remain much less common. Bennett et al (2010) carried out a study of the impact of courses provided by Science Learning Centres across England, including one-day courses, and noted that, 'In all cases there was evidence that information and resources provided on courses resulted in some adaptation or change in participants' teaching.' (ibid, p17). A second Science Learning Centre study into the impact of courses, focused on the development of teachers' subject and pedagogical knowledge, found, '… there being a real and sustained impact on teacher knowledge and understanding of fundamental chemistry and physics concepts through a *short CPD intervention*, with direct, on subject, contact time of the order of 4/5 hours.' (Scott et al, 2010, p1). Thus elements of this more recent research support the ESEU findings that short courses focussing on subject knowledge and pedagogy can have measurable impact on teaching in schools.

7. Industry/Education Partnerships – the case for sponsoring professional development

Since, in 1956, Russell listed 11 different types of industry/education partnership, including apprenticeships, offering speakers or career guidance, providing published materials and sponsorship, there seems to have been little published in the science education literature or in the professional development literature about industry/education partnerships. The sponsorship described by Russell (1956) was in the form of scholarships, prizes, etc. and so was very different from the oil industry sponsorship of the ESEU.

The material that has been published about industry/education partnerships more recently has mostly focussed on vocational education and internships (e.g. Ball et al, 1995; Winistorfer, 2005; IISME website), scientists from industry visiting schools (as mentioned by Stocklmayer et al, 2010) or focussing on local projects, such as that described by Tytler et al in Australia (2011) and the guidance offered in its, '*Guide to Industry/Educational Collaborative Projects'*, by the Irish Medtronic Scientist of the Future Project (MSFP website). In 2008, the European Round Table of Industrialists declared, 'Business can contribute to enhancing the role of teachers by providing in-service training on MST [maths, science and technology] topics, resources and contexts …' (ERT, 2008, p5), whilst the UK Department for Business, Innovation and Skills (DBIS), in its summary of responses to its '*Science and society'* document, found arguments to, 'increase connectivity between the science community, the media, education and industry (p3), for, 'More partnership working between the Government, Education, Business and Scientists' (p5), promoting, 'High quality science education available to all, leading to a scientifically literate public.' (DBIS, 2009, p27).

Despite these on-going pleas for industry/education partnership development, there seems to be no readily available published literature or anecdotal evidence for an industry/education partnership like that of the Earth Science Education Unit. It seems that nowhere else is industry providing funding for an initiative offering professional development to teachers free-of-charge on a sustained basis. Moreover, anecdotal evidence suggests that many industry/ education partnerships develop with the goal of publicising the company or industry concerned, and they carry out little research into the impact of their initiatives on classroom teaching and learning.

For these reasons, it is arguable that the Earth Science Education Unit initiative is unique, or at least, very uncommon, as an industry/ education partnership providing a national professional development programme, focussed on the mainstream curriculum, which is not used as a promotional tool for industry, and has demonstrated its effectiveness through research.

8. ESEU's Broader Impact

Over the years of its activity, the ESEU's impact has been broader than solely the training of science and primary teachers, including the following:

- ESEU has supported the Earth Science Teachers' Association in the UK (ESTA website) by joining all its facilitators to ESTA, by offering workshops at ESTA conferences and at other conferences on behalf of ESTA (e.g. the annual national Association for Science Education conference – ASE website), and by encouraging participants in ESEU workshops to become ESTA members;
- ESEU has supported the work of the Earth Science Education Forum (ESEF) in England and Wales (ESEF website) and the Scottish Earth Science Education Forum (SESEF website);
- ESEU used funding provided by the Wellcome Trust as part of its '*Creative Science'* initiative to develop new materials for the prospective Science Learning Centres through six workshops enabling biology, chemistry and physics teachers to teach science through earth contexts. This was one of the few most successful *'Creative Science'* projects (see King, 2007 for more details), that was later rolled out through the Science Learning Centre network (SLC website). The workshops developed are shown in Table 9;
- ESEU worked with the Institute of Physics (IoP website) to develop three workshops aimed at helping physics teachers of 14 – 19 year olds to teach physics through earth contexts (Table 9) – that were made available nationally.

Table 9. Additional workshops developed by ESEU.

Initiative	Age Range	Workshops	
Prepared for the Darwin anniversary	11 – 16 years	*Darwin the geologist*	2009
ESEU's 'Earth Physics' initiative	14 – 18 years	*Tackling climate change through Earth physics*	2009
		Earth physics: the geophys story	
		Earth physics: the seismology story	
Wellcome Trust's 'Creative Science' initiative	14 – 16 years	*Dead and buried?: teaching KS4 biology through an Earth context*	2004
		Chemistry of me at 16: teaching KS4 chemistry through an Earth context	
		Sensing the Earth: teaching KS4 physics through an Earth context	
	11 – 14 years	*Life on Earth: teaching KS3 biology through an Earth context*	
		Science under the limelight: teaching KS3 chemistry through an Earth context	
		Through the lab window to the world: teaching KS3 physics through an Earth context	

- the ESEU approach formed the basis of a bid for International Year of Planet Earth (IYPE website) funding by the International Geoscience Education Organisation (IGEO website) and the International Union of Geological Sciences Commission on Geoscience Education (IUGS/COGE website) to pilot ESEU strategies in four developing countries. Unfortunately, the bid was not successful;
- after the lack of success of the IYPE bid, three ESEU facilitators decided to work on a voluntary basis to develop a website offering ESEU and other activities as resources to teachers and teacher trainers across the developing and developed worlds. The initiative, called Earthlearningidea (ELI website) is described in King et al (in press). Currently Earthlearningideas are being published at a rate of one per fortnight and by September 2011, 113 activities had been published in English with a further 50 in the pipeline; ELI activities had been translated into Chinese (Mandarin), German, Italian, Norwegian, Portuguese, Spanish, and Tamil and accessed in 167 countries and 8579 towns/cities worldwide with 472,073 pdf downloads of Earthlearningidea activities globally, averaging nearly 20,000 per month over the past year. The activities had been used as the basis of teacher education workshops in Argentina, India, Italy, South Africa, Taiwan, UK and the USA, some led by the Earthlearningidea volunteers; others by the local science educators in those countries;
- ESEU has formed an important element of the sustainability strategy of Oil and Gas UK, the ESEU sponsoring organisation, by increasing the impact of the Earth science component of science education nationally, so increasing national understanding about Earth science-related issues and encouraging more young people to consider earth science-related careers.

9. Conclusions

As with any successful and sustainable joint venture it is critical that partners make their expectations explicit and there is absolute clarity about what will constitute success for each stakeholder from the outset. A major challenge, which when managed well becomes an enormous opportunity is the different professional expertise within an industry/ education partnership. It is a challenge because each party needs to appreciate and respect the different contexts they operate in. However, if this mutual understanding and respect is established, then opportunities are created through the combination of the complementary skills of the partners.

This review of twelve years of ESEU activity has shown the impact that an innovative, well-supported and well-researched industry/education initiative can have on the education system. It has also shown that, contrary to much of the published evidence on the evaluation of professional development, short well-planned and delivered workshops can have long-term impact on teaching.

The review has also shown how an educational initiative that is successful in one country can be taken successfully to another jurisdiction. Many readers might not be aware that the education system in Scotland is very different from that in England, in a number of ways. For example, children in Scotland move from primary to secondary school one year later than in England, the Scottish curriculum and assessment system are completely different, and in Scotland there is more emphasis on teaching 'separate sciences' (biology, chemistry, physics) at secondary level than in England, where 'broad science' is more commonly taught. This experience has allowed the ESEU to prepare guidance to those planning to launch educational initiatives in new jurisdictions, as shown in Box 1 below.

Box 1

To launch a workshop-based educational initiative, like that of the ESEU, successfully in a new jurisdiction, the following aspects appear to be critical:

- the content of the workshops must be part of the national curriculum or national standards;
- suitable materials must be available, for use in for devising workshops;
- teachers and educators in the jurisdiction concerned must be involved in the development of the workshops;
- workshop materials should be hands on, interactive, and capable of being implemented easily in schools;
- the materials should be well-presented, with teacher guidance;
- an enthusiastic leader or team is needed to lead the initiative;
- significant and sustained funding is required to develop professional development workshops and take them free-of-charge to schools and teacher training institutions; this allows a network of workshop presenters to be identified, trained and paid to take the workshops to the institutions concerned;
- because of the 'gearing' involved, it is much more efficient to present workshops to teachers than to pupils;
- similarly, it is more efficient to present workshops to trainee (pre-service) teachers than to practising teachers, since trainees will generally teach for longer than practising teachers and, by visiting the same institutions annually, a new group of trainees can receive the workshops each year;
- effective methods of evaluation should be in place during all stages of the initiative so that success and impact can be demonstrated to all the parties involved.

Over the ten years of ESEU activity, success has been demonstrated by the longevity of the project, the numbers of individual teachers and trainee teachers reached (more than 23,000) and the numbers of pupils potentially affected (several millions). Effectiveness has been shown by the ESEU research demonstrating good participant feedback and long term changes to schemes of work in schools.

The approach of ESEU may be unique, since no anecdotal evidence or evidence from the literature has been found describing successful industry/education partnership interventions of this type elsewhere. It seems that nowhere else are free-of-charge mainstream curriculum-based professional development workshops provided to schools and Teacher Education institutions on a consistent and sustained basis.

10. The Future

This review has focussed specifically on the outcomes of the support for the ESEU provided by the upstream (exploration and production) oil and gas industry in the UK. However, the availability of scientists and geologists in particular is increasingly becoming an issue for other industrial sectors as indicated in the following extracts from the recent UKCES Report (2010),'Current and projected shortages of skills in the sector, particularly in relation to STEM subjects (Science, Technology, Engineering and Mathematics), means that the low carbon sector will need to compete for STEM graduates with industry as a whole.' (px). '… the ability to attract STEM students at all levels … amidst growing demand for such skills across industry as a whole, will influence the sector's ability to develop and maintain a highly skilled workforce;' (p120). 'The view that the sector itself has a key role to play in terms of engaging education providers and encouraging the uptake of STEM subjects is supported by the Council for Industry and Higher Education's STEM Review (CIHE, 2007)' (p121).

The increasing demand for STEM skills in the UK and internationally is well-documented and is expected to become more acute as, from school level onwards, fewer students opt for these subjects. This creates a vicious circle, with shortages in the teaching supply for STEM subjects already reported across developed countries (OECD, 2005).

Concerns around the number of school-age students opting for STEM subjects at GCSE and A-level, coupled with a reported shortage of teachers in STEM subjects in the UK (OECD, 2005), are likely to exacerbate the supply of STEM students unless steps are taken to make not only these subjects, but also related careers more attractive.

It is against this backdrop that the ESEU is working towards engaging with a wider industry cohort than just oil and gas. Alongside this ambition ESEU is seeking to extend its current offering, of continuing professional development for science teachers, to include the provision of support to the supply of subject-specialist geology teachers to ensure that A-level geology remains an available option as a post-16 examination subject for students in the UK. Additionally, it is hoped that greater knowledge transfer and better coordination of the various organisations already involved in Earth science education can be achieved through a more focussed network approach. One strategy currently being explored is to establish an earth science education consortium which would provide both a forum for existing providers but would also include other stakeholders such as government agencies and examining bodies.

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