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Educating science teachers in earth science teaching: the Earth Science Education Unit initiative in England and Wales, and its transfer to Scotland

Chris King and Susannah Lydon

Summary

The Earth Science Education Unit (ESEU) presents professional development workshops to secondary (high school) teachers and trainee (pre-service) science teachers in England and Wales and to upper primary (elementary) teachers in Scotland. The workshops enhance the background Earth science knowledge of the teachers, through showcasing a variety of engaging Earth science activities which enhance effective use of practical activities in science whilst developing critical thinking and investigational skills in pupils.

Research into the impact of the workshops in England and Wales has shown that the activities are widely taken up in the schools visited and that most schools subsequently change their long-term science planning to include ESEU activities. A key element is the increase in confidence and enthusiasm of the staff involved. Word frequency analysis of written feedback has shown that trainee teachers referred to evidence and theory more frequently than practising teachers, while practising teachers used terms relating to positive affective responses more frequently than trainees. These differences may relate to the changing CPD needs of teachers at different career stages.

ESEU has successfully transferred its approach to the quite different educational environment of Scotland, as shown by the numbers of teachers undertaking the workshops and their very positive responses. As a result, key factors have been identified that need to be present in order to successfully transfer the ESEU approach to other countries. An international survey has identified developing countries where these factors are present, as a precursor to submitting a bid for International Year of Planet Earth funding, to pilot the ESEU approach in these countries.

The Earth Science Education Unit

The Earth Science Education Unit (ESEU) uses a network of specially appointed and trained facilitators to present Professional Development workshops to practising (in-serv-

ice) and trainee (pre-service) science teachers. Earth science forms a small but significant component of the national curriculum for science in England (DfES, 2004) and in Wales (ACCAC, 2000) and the

environmental studies guidelines for Scotland (Scottish Executive, 2000). ESEU's workshops are aimed directly at the Earth science content of these curricula and educate teachers through a series of 'hands on' activities that can be used directly with pupils. Most of the activities are practical and interactive and have been chosen to enthuse and motivate pupils, to be relevant and interesting to them and to develop their thinking and investigational skills. Through testing and demonstrating these activities, the teachers encounter new strategies that can be translated directly into the classroom/laboratory while developing their own background knowledge of Earth science.

The ESEU is able to offer these workshops to science teachers and trainee teachers free of charge (apart from expenses), thanks to sponsorship from the trade association of the UK offshore oil industry, UKOOA. UKOOA first supported a pilot ESEU operation between 1999 and 2001. Based on the success of this pilot, UKOOA funded a five-year national rollout of the workshops to progressively cover the whole of England and Wales and to launch into Scotland in 2004. This rollout has been so successful that UKOOA has recently agreed another five-year tranche of funding, to 2011, to support current activities and to develop and rollout workshops for primary (elementary) teachers in England and Wales.

This paper:

- evaluates the success and impact

of the ESEU strategy in England and Wales, based on a presentation to the GeoSciEd 5 conference (LYDON & KING, 2006) and

- discusses the success of transferring the ESEU strategy from England and Wales to Scotland, based on a second presentation at the GeoSciEd 5 conference (KING, 2006).

Background research

The ESEU was instigated on the basis of background research (KING, 2001) which had shown, through a survey of secondary (high school) teachers teaching Earth science as part of the National Curriculum for Science that, in the parts of England and Wales surveyed,

- the educational background of the teachers in Earth science was poor (nearly two thirds had received no Earth science teaching in their previous education and most of the rest had received only a little);
- they were fairly confident in their teaching of Earth science and felt their pupils performed reasonably well, nevertheless,
- they used very little practical work in their Earth science teaching, and hardly any fieldwork;
- their main source of background Earth science information was science textbooks written for pupils.

Subsequently, a survey of the science textbooks commonly used in schools for their Earth science content was carried out (King et al,

2005). This showed that the overall coverage of Earth science by the textbooks was inadequate, with a very high error level (averaging one error per page of Earth science). Thus teachers who relied on these textbooks for their background knowledge of Earth science were often being badly misled.

Since this initial work, ESEU has been steadily collecting a database of background information on Earth science teaching in Britain. This larger sample has shown that whilst 26% of teachers teaching Earth science have received no Earth science teaching in their own education, 45% received some teaching while they were at school and 23% received some Earth science teaching in their university degrees. This is a better situation than indicated by the KING (2001) research, but still shows that the background education of teachers in Earth science is mostly much lower than that in their other science subjects, biology, chemistry and physics.

ESEU workshops in England and Wales

Since 1999, in England and Wales, ESEU has presented more than 600 workshops to over 4100 practising (in-service) teachers and 4400 trainee (pre-service) teachers. Between them the teachers were teaching more than a million school pupils. Over this time the most popular workshop has been 'The dynamic rock cycle' for 11-14 year olds (40% of all workshop bookings in 2003/4) followed by 'The plate tectonic interactive' (14 – 16 year olds, 25%) and 'Spot that rock' (11-14 year olds, 13%), 'Earth and atmosphere' (14 – 16 year olds, 10%) and 'Earth science out of doors' (all pupils, 9% of bookings in 2003/4). Following every workshop, participants are asked to 'score' the experience on a 1 (high) to 5 (low) Likert scale for the aspects shown in Figure 1.

These high scores reflect those of previous and subsequent years and show a high level of satisfaction by participants of the professional development they received.

Indicator		Mean 'score'
Mean evaluation 'scores' of each participant on a 1 – 5 scale in each of the categories shown, (where 1 is a high rating).	workshop effectiveness	1.71
	workshop interest	1.69
	workshop relevance	1.67
	workshop value	1.75

Figure 1: Feedback from participants in 2003/4 (n = 1344)

Prompt	Percentage scores on Likert scale					
	1	2	3	4	5	Not applicable
	'strongly agree'				'strongly disagree'	
"The workshop has improved my Earth science knowledge and understanding"	42	40	14	3	1	0
"The workshop has given me new ideas for ways of teaching Earth science"	56	34	6	2	1	2
"The workshop will increase the amount of Earth science practical work I teach"	43	41	11	2	1	2
"The workshop will increase the amount of Earth science investigational work I teach"	24	40	27	3	1	3
"The workshop has improved my confidence in teaching Earth science"	29	48	18	2	1	2

Figure 2: Participant response to 'prompt questions' in 2003/4 (n = 1344)

The participants were asked a number of follow-up questions and their responses on a 1 to 5 Likert scale are shown in Figure 2.

Thus participants feel that the workshops did increase their background knowledge and understanding, with new ways of teaching Earth science, and intend to increase the practical content of their Earth science lessons. Their feeling was less strong, but nevertheless still strong,

that they would increase the amount of investigational work they would teach and that their confidence had increased.

The ESEU strategy has tried to ensure that the new knowledge and ideas become embedded, by involving participants closely in all the steps of the workshop. To do this, workshop activities that introduce the concepts and processes being

considered are initially carried out in pairs or small groups. Participants then test out one of a circus of activities in pairs before demonstrating the activity to the whole group. During demonstrations, the facilitator encourages discussion around how each activity could be used in particular teaching contexts. There is normally a plenary activity that tries to draw all the elements of the workshop together. Thus all the workshops have the elements of practice, feedback and coaching that research has shown (JOYCE & SHOWERS, 1988) are critical for transferring good practice to the classroom. Nevertheless, the fact that participants underwent these processes and felt good about their workshop experience, when asked afterwards, does not necessarily mean that they will transfer their intentions into improved teaching in the classroom.

The impact of ESEU workshops in England and Wales - postal questionnaire response

The surest way of establishing whether the strategies designed to ensure that ESEU workshops cause lasting change have been effective, is by following up the workshops. Thus ESEU contacted all the 46 school science departments to which 'The dynamic rock cycle' workshop had been presented in 2003/4, approximately a year after the workshop, inviting them to contribute to a postal questionnaire. After strenuous effort, a 33% response rate was achieved (15 schools).

Through the questionnaire, a member of the science staff was asked:

- for each workshop activity, what proportion of the staff used the activity:
 - a) before the workshop, b) after the workshop
- what were the main barriers to introducing new activities like these
- had the school science 'Scheme of work' (an official document setting out how the school plans to teach the National Curriculum) been altered to include new activities as a result of the workshop

The results of this research were as follows.

Usage of each workshop activity: All schools had increased their use of the activities. Of the 12 activities in the workshop, on average, schools were now using six of these that they hadn't used previously.

The levels of change varied between schools. Five reported increased use of some activities by some staff, four of the schools reported more use than this and six schools recorded that activities which were new to all were now used by all staff in the school. Several schools also mentioned the positive effect of the workshop on staff motivation and enthusiasm.

Barriers to introducing new activities: Where take up of the activities had been lower than might have

been expected, the major barriers reported were lack of time to institute changes; lack of suitable resources; concerns that some of the activities were more 'messy' than other practical science activities, and concerns about whether or not the activities were strictly relevant to the curriculum.

Change to 'Schemes of work': Schools are required to have 'Schemes of work' for all the major subject areas such as science. Schools often follow standard schemes but are encouraged to adapt them to suit the teaching staff, the pupils and the school circumstances. The 'Scheme of work' is a long-term planning tool through which day to day changes in teaching are implemented.

The survey established that of the 15 schools that responded, 13 had revised their 'Scheme of work' and one was planning to do so whilst the other school did not write its own 'Scheme of work'.

Review of the follow-up questionnaire research findings: The response of this sample of all the schools visited in 2003/4 was much more positive than might have been anticipated from research into effective Professional Development elsewhere (JOYCE & SHOWERS, 1988; ADEY, 2004). It is very significant that all schools reported changes in their teaching, and that many of the schools reported changes in the day to day use of activities as great as could be expected. Even more sig-

nificant are the changes to 'Schemes of work' that indicate impact of the workshop over the long term in effectively all the schools visited. The reports of increased staff motivation and enthusiasm are also important, indicating that what might previously have been presented as a very 'dry' subject area, was being 'brought to life' through new enthusiasm by the teachers using a range of new practical activities.

The impact of ESEU workshops in England and Wales - word frequency analysis of questionnaire evaluations

The follow-up questionnaire work, coupled with a range of other anecdotal evidence, has shown that the motivation and enthusiasm of the science teacher are critical factors. Thus further research on this aspect has been carried out, based on the language used in the written comments on questionnaire feedback from ESEU workshops from 2003 to 2006. The written responses of 1007 practising teachers have been compared with those of 1877 trainee teachers.

The participant responses which were analysed, addressed the following question: "Please describe, in a couple of sentences, which aspects of the Earth science content were of the most value to you". Responses for practising teachers and trainee teachers were collated separately, to form a single 'corpus' for each group's response to the question. Standard text analysis

software was then used to calculate the frequency with which words were used in each corpus, and to present this information as a word frequency list, in order of decreasing frequency. The 20 most common words in the English Language found in the British National Corpus (the, of, and, a, in, to, it, is, etc.)

were then removed from each list (a standard technique used in text analysis to prevent very common words from obscuring meaningful patterns).

Figure 3 shows the ten most common terms (after removal of very common words as described above) used by

Question: "Please describe, in a couple of sentences, which aspects of the Earth science content were of the most value to you"			
Participants in workshops for practising teachers, n=1007		Participants in workshops for trainee teachers, n=1877	
WORD	FREQUENCY	WORD	FREQUENCY
practical	211	practical	372
ideas	129	practicals	262
rock	117	ideas	239
experiments	99	experiments	208
practicals	86	rock	200
rocks	82	plate	155
activities	80	cycle	128
cycle	58	activities	120
demonstrations	51	rocks	108
use	48	tectonics	107

Figure 3: Most frequently used terms by ESEU workshop participants in questionnaire responses

Question: "Please describe, in a couple of sentences, which aspects of the Earth science content were of the most value to you"							
Participants in workshops for practising teachers, n=1007				Participants in workshops for trainee teachers, n=1877			
Rank-ing	Word	Frequency	% of all words	Ranking	Word	Frequency	% of all words
46	knowledge	22	0.37	42	knowledge	53	0.48
64	understanding	18	0.30	62	understanding	33	0.30
72	explanation	16	0.27	67	misconceptions	30	0.27
74	misconceptions	15	0.25	77	evidence	25	0.23
79	information	13	0.22	78	theory	24	0.22
86	concepts	12	0.20	82	concepts	22	0.20
143	info	7	0.12	91	explanations	20	0.18
161	explain	6	0.10	97	information	19	0.17
177	evidence	6	0.10	99	explanation	18	0.16
				109	revision	16	0.14
				115	content	15	0.14
				120	relevant	14	0.13

Figure 4: Frequency of terms related to knowledge and understanding in questionnaire responses, comprising 0.1% or more of the total number of words in the corpus.

each group. Trainee and practising teachers used a similar range of terms, relating to the nature of the workshop ("practical", "experiments", "activities"), the content of the workshop (the rock cycle and plate tectonics) and their experience ("ideas", "use").

Figure 4 shows the frequency with which terms relating to knowledge and understanding were used by the two groups. Frequency values for each term are given as a percentage relative to the total number of words in each corpus (allowing quantitative comparisons to be made between the two), with a cut-off point of 0.1% applied to each group.

Both practising and trainee teachers used terms such as "knowledge", "understanding", "misconceptions" and "concepts" to a similar degree, as well as terms relating to explanation and information. However, differences were also observed. Trainee teachers used the term "evidence" with a relative frequency more than double of that of practising teachers, and the term "theory" was used much more frequently by trainees than by practising teachers (for whom it fell below the 0.1% threshold). "Revision", "content" and "relevant" were other terms used more frequently by trainees than by practising teachers. A possible explanation for these differences is that trainee teachers have more concerns about acquiring the subject knowledge necessary to

underpin their teaching, while their more experienced colleagues are less worried about improving their 'formal' understanding of the subject.

Figure 5 shows the word frequency results for terms relating to affective responses to the workshops. Both groups frequently used terms relating to their interest in the workshop, and the term "fun" was used at a similar frequency by both. Practising teachers used the terms "enthusiasm", "confidence" and "engage" more frequently than did trainees, perhaps reflecting a greater appreciation for the fostering of these affective elements of training (whereas trainees participate in workshops within a wider training programme, and may be less reflective about the effects of a single training episode on their attitude and emotional response).

Review of word frequency analysis findings: although a fairly crude tool, word frequency analysis has provided a means of comparing large numbers of written responses in a quantitative way. This method has been particularly useful in showing how reactions of trainee teachers may differ from those of practising teachers, since follow-up studies of trainee teachers are problematic and impractical. In summary, both trainee and practising teachers valued the practical format of the workshops and the teaching ideas provided. Trainee teachers referred to evidence and theory more frequently than practising teachers, while practising teachers used terms relating to positive

Question: "Please describe, in a couple of sentences, which aspects of the Earth science content were of the most value to you"							
Participants in workshops for practising teachers, n=1007				Participants in workshops for trainee teachers, n=1877			
Ranking	Word	Frequency	% of all words	Ranking	Word	Frequency	% of all words
47	interesting	21	0.35	36	interesting	59	0.53
124	interest	8	0.13	175	enjoyed	9	0.08
151	enthusiasm	7	0.12	193	fun	8	0.07
238	confidence	4	0.07				
308	engage	3	0.05				
317	fun	3	0.05				

Figure 5: Frequency of terms related to affective responses in questionnaire responses, comprising 0.05% or more of the total number of words in the corpus

affective responses more frequently than trainees. These differences may relate to the changing CPD needs of teachers at different career stages.

ESEU in Scotland – transferring experience from England and Wales

Education in Scotland has evolved separately from that in England and Wales and so it has a wide range of differences. This is highlighted by the view of the British Council, that: 'While the education and training

systems of England, Wales and Northern Ireland are broadly similar, the education system in Scotland has always been a completely separate system with its own laws and practices.' (British Council Learning website).

Major differences between the two systems are shown in Figure 6.

As far as the teaching of Earth science is concerned, the major difference is that in England and Wales,

Topic	England and Wales	Scotland
Primary (elementary) education	from 5 - 11	from 5 - 12
	small amount of Earth science; in science and geography curriculum	important Earth science content; in environmental studies curriculum
Secondary (high school) education	from 11 – 16	from 12 – 16
	most Earth science in science curriculum; some in geography	no Earth science in science; some in geography
Assessment	in science at ages 7, 11 and 14	no assessment in science before 16
	formal examinations at: 16 (GCSE) 17 (AS-level) 18 (A2-level)	formal examinations at: 16 (Standard) 17 (Higher) 18 (Higher still – taken by only a few students)

Figure 6: Contrasts in the educational systems of England/Wales and Scotland

most Earth science is taught in secondary schools by secondary science teachers, whereas in Scotland, most Earth science is taught in primary schools by primary teachers. Thus the main teachers of Earth science in England and Wales are specialist science teachers (usually of biology, chemistry and physics), whilst most of the teachers teaching Earth science in Scotland are generalist teachers, many of whom have poor science backgrounds and have never experienced any Earth science teaching.

The content of the curricula in the different countries is different too, since much of the geological content of the curriculum is included in the National Curriculum for Science

in England and Wales (DfES, 2004) while it is part of the Environmental Studies recommendations in Scotland, which broadly cover history, geography, science and technology together (Scottish Executive, 2000).

ESEU responded to the challenge of providing effective professional development in the very different educational scenario of Scotland, by first developing a close relationship with a pre-existing network keen to promote Earth science education in Scotland – the Scottish Earth Science Education Forum (SESEF). This allowed ESEU to get a feeling for the most effective strategies to reach teachers of Earth science in Scotland. The next

step was to prepare professional development workshops. This was done in collaboration with Scottish primary teachers, using the expertise of ESEU and of SESEF over a three-day writing workshop, during which two 90 minute-long workshops were devised and tested. The two workshops, 'Science through the window' and 'Scotland's journey' involved a range of practical, hands-on activities, some of which were existing ESEU activities and some that were newly devised. 'Science through the window' focussed on the sedimentary cycle, whilst 'Scotland's journey' dealt with deep Earth processes and plate tectonics. These workshops were then trialled in local schools and then written up and published for use by teachers attending workshops. Each was associated with a range of key photographs provided with the written materials on a CD ROM and a geological map of Scotland, while 'Scotland's journey' also had an associated rock box – given free of charge to participating schools.

Meanwhile the position of ESEU/SESEF facilitator was advertised and interviews took place. Ten individuals were appointed and trained in delivering the two workshops and were then provided with the necessary 'kit'.

In England and Wales, ESEU workshops were offered to individual secondary schools, but this was not possible in Scotland, since there are far too many primary schools for a

visit to each one to be practicable. Thus the SESEF Development Officer was partially funded by ESEU to contact Local Authorities across the country. These were invited to gather primary teachers together in central locations for the workshops to be delivered, whilst widespread advertising took place to support this offer. As in England and Wales, mechanisms were set up to monitor the impact of the workshops.

The success of ESEU workshops in Scotland

The success of the ESEU approach in Scotland has been judged on the numbers of teachers involved in workshops and from their feedback. During the piloting in 2003 and the national rollout in 2004/5, 52 workshops were presented to 858 teachers. The teachers were asked to 'score' the workshops in the same way as teachers in England and Wales, on a 1 (high) to 5 (low) Likert scale for the aspects shown in Figure 7.

This shows an even higher 'satisfaction level' with the workshops than the high levels for England and Wales (Figure 1) and demonstrates that the workshops were very well received on the day. It also demonstrates the success of the first year rollout of workshops in Scotland. The mean primary school class size in Scotland (2003 figures – Scottish Executive website) is 24, suggesting that the 858 teachers involved in 2003/5 will be teaching more than 20,000 children per year with the

Indicator		Mean 'score'
Mean evaluation 'scores' of each participant on a 1 – 5 scale in each of the categories shown, (where 1 is a high rating).	workshop effectiveness	1.39
	workshop interest	1.33
	workshop relevance	1.39
	workshop value	1.39

Figure 7: Workshop feedback from 858 participants in 2003/5

enthusiasm and materials gained from their workshop experience.

Transferring ESEU strategies from one country to another

The success of ESEU's work in Scotland indicates that, providing the following series of factors is taken into account, the strategy should be transferable to any other country successfully as well.

- Earth science must form part of the national curriculum - in Scotland it forms a significant part of the 'Environmental Studies' recommendations.
- There must be funding available to support the initiative – for Scotland, funding was provided by the oil industry (UKOOA) to extend ESEU activities to Scotland.
- There must be a support network in the country – SESEF already existed in Scotland.
- Working with local teachers is crucial – in Scotland the new workshops were devised with the collaboration of local primary

teachers and Scottish Earth science educators.

- Workshops must be piloted – the ESEU Scottish workshops were piloted with 12 workshops and 124 teachers in the Aberdeen area.
- Local facilitators must be appointed and trained – 10 were appointed in Scotland
- A booking and promotional office must be maintained in the country concerned – the SESEF Development Officer works as ESEU's agent in Scotland.
- The progress of the initiative must be closely monitored – this role has been carried out by the ESEU Research Officer, in collaboration with the SESEF Development Officer in Scotland.

The ESEU approach – the future

The success of the ESEU national roll-out between 2002 and 2006 in England, Wales and Scotland, as demonstrated by the monitoring and research findings, underpinned a bid to the oil industry (UKOOA) for further funding for the next five

years. The bid was successful so that UKOOA will provide approaching £1 m of funding to maintain ESEU's current work across Britain as well as to develop and roll out primary workshops in England and Wales through to 2011.

The International Year of Planet Earth (IYPE website), focussed on 2008 (but running between 2007 – 2009) is sponsoring outreach work as part of its international activity. ESEU is currently preparing a bid, supported by the International Geoscience Education Organisation (IGEO website) and the International Union of Geological Sciences, Commission on Geoscience Education and Technology Transfer (COGE website) for funding to pilot ESEU strategies in developing countries. Suitable countries have been chosen, on the basis of a questionnaire survey carried out by IGEO seeking those countries in which the factors listed above were present. If the bid is successful, the ESEU approach will be piloted in one or more developing countries and, during the pilot, further funding will be sought to maintain the initiative in each country beyond the International Year of Planet Earth.

If research accompanying each of these pilots shows that the ESEU approach is effective in promoting ESEU objectives of:

- enhancing the background Earth science knowledge of teachers and trainees;
- showcasing a variety of engaging

Earth science activities;

- enhancing effective use of practical activities in science;
- developing critical thinking and investigational skills in pupils,

... then further funding will be sought to take ESEU strategies to other countries across the globe.

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