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

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

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

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Introduction

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

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

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

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

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

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

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

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

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

Theoretical Context

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

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

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

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

Research Question

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

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

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

Methods

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

The Learning Tasks

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

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

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

Task Authenticity

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

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

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

§ n = 7

* Statistical significance at the 90% level

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

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

and be able to:

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

and:

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

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

Measurement and Comparison of Student Perceptions

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

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

Measurement and Comparison of Academic Achievement

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

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

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

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

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

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

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

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

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

Limitations of the Study

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

Results

Student Perceptions of Field and Laboratory Work

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

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

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

Student Perceptions of the Two Tasks

Student Preferences

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

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

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

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

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

Student Perceptions of Task Value

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

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

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

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

Academic Achievement

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

Discussion

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

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

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

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

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

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

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

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

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

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

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

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

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

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Appendix: The Learning Exercise as Presented to the Students

Learning About Invertebrates Through Sorting and Interpreting Collections

Learning Objectives

Students who have completed the exercise will be able to:

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

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

The Learning Exercise

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

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

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