Biology fieldwork in school grounds: a model of good practice in teaching science

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Three case studies which illustrate how easily organised outdoor investigations can bring science to life

Professor Anthony Campbell (Campbell, 1994) has observed that many big ideas in science have been inspired by observations of the natural environment. The images of Newton and his falling apple, Galvani and his twitching frog's legs and Charles Darwin overwhelmed by Galapagos biodiversity certainly support this idea. Campbell's own childhood fascination for bioluminescence of glow worms and of marine plankton in waves breaking on the shore led him to elucidate the underlying biochemistry of the process. This, in turn, led him to make a major breakthrough in diagnostic medicine (Campbell, 1988).

All science, chemistry and physics as well as biology, can come alive by getting out of the classroom. Indeed, science that does not make the connection between looking in wonder at the natural world and scientific enquiry is incomplete. Making such a connection is an essential part of understanding science as an intellectual process. Newton, Galvani and Darwin have long since passed away, but their source of inspiration still remains – at least partly – outside the classroom.

ABSTRACT

Direct observation of the environment and practical scientific enquiry outside the classroom are fundamental to an understanding of the nature of science as well as a source of inspiration and motivation. Outdoor biology is a well-developed tradition in the UK and provides many examples of good practice that could profitably be extended to the teaching of other scientific disciplines. Three case studies are presented that illustrate good practice in science teaching, whilst minimising cost and timetable disruption by making use of school grounds.

There are a number of reasons why fewer classes experience outdoor science than used to be the case. These are discussed by Barker, Slingsby and Tilling (2002) and include concerns about health and safety, expense and time out of the normal school timetable for both students and teachers. Yet these problems can be overcome much more easily than many think. It is a question of '*where there's a will there's a way*'. The outdoors has such a lot to offer science teaching that any modest problems are well worth overcoming.

A great deal can be achieved, quite inexpensively, in the relatively non-hazardous environment of the school grounds during normal timetabled lessons. A great advantage of this is that fieldwork can be incorporated into a science course as a series of short episodes of outdoor activity over a period of time. School grounds need not be extensive to be useful for outdoor science, although there are ways in which they can be developed to enhance their potential. The construction of a pond is an obvious project worth undertaking, especially if it is designed to maximise biodiversity. An area managed as a nature reserve or conservation area could also be very useful.

The case studies that follow have all been tried, tested and enjoyed by students and teacher alike. Fine weather is not essential, though desirable: umbrellas and waterproofs can even add to the 'differentness' of a lesson! Working effectively outdoors and in a well-organised fashion, irrespective of the weather conditions, is something that develops with experience. Indeed, it is important in a range of careers. Some of the activities described here have been developed over a number of years, and the source of the original inspiration has been forgotten, so if ideas have been stolen without acknowledgement, please accept our apologies and take it as a compliment.

Case study 1: The effects of abiotic factors in artificial ponds

In this activity, two (or more) recently established or recently cleaned out ponds in different locations are compared in terms of their biotic and abiotic components through open-ended enquiry. The use of buckets or washing-up bowls as temporary, artificial 'ponds' as an alternative when real ponds are not available is described. The system provides a means to investigate the influence of abiotic factors on the subsequent successional processes.

Ideally the activity would benefit from access to two contrasting ponds, although one pond would be quite satisfactory provided that different areas within it can be compared, for instance opposite ends or shallow versus deeper water. However, if no pond is available an artificial system can be created using plastic washing-up bowls or buckets. The smaller surface area of buckets as opposed to bowls means that not only is water loss by evaporation reduced but also the rate at which oxygen can diffuse through the water surface from the air. Both bucket and bowl containing equal depths of water could be set up in the same area to compare the effect of surface area on the rate of evaporation. Alternatively, two identical buckets containing equal volumes of water could be left in different areas that are not likely to be disturbed. In schools where vandalism is a problem the buckets could be placed on a flat roof, provided that this can be done safely.

Planning and procedure

Forward planning is needed to decide locations to use and when to set up 'ponds'. They could be set up before the summer holidays and checked in the autumn term. If tap water is used a period of at least a month is usually needed to allow time for bird/air-borne material to reach the pond and grow sufficiently to be detected and living organisms seen. This could be kept as an on-going project, with samples being taken and looked at under microscopes at regular intervals and a log being kept. The concepts of primary succession could be studied by A-level students (16–18 year-olds). The optical density of the water should increase as the biomass accumulates and animal life should increase as primary producers proliferate.

Curriculum slot

To fit in with any part of the curriculum dealing with adaptations to the environment, ecological change and the effect of abiotic factors. English National Curriculum (QCA, 2004) key stages 3, 4 and 5 (ages 11–18).

Figure 1 Using 'real' ponds to study abiotic factors.

Different locations, if chosen well, are likely to have different abiotic and biotic factors such as:

- shade/light exposure;
- aspect;
- frequency of visits by flying animals;
- quantity of air-borne material deposited (dropping leaves, seeds, pollen, bird-dropped material/guano;
- temperature.

Recording the appearance and proliferation of species could involve the use of microscopes. Colorimeters can be used to monitor deviation in optical density from a fresh tap-water sample. The water develops a green coloration and optical density increases surprisingly quickly as biomass accumulates. The level of species identification and the degree of qualitativeness will depend on the class.

Planning a 'fair' test, with only the location changing, would help to set the scene and get the students involved in setting up the investigation.

Quicker results will be obtained in warmer weather, but care needs to be taken to avoid the artificial ponds drying up. In warm weather meaningful results can be obtained in as little as one month.

Resources

The following will be needed or useful:

- ponds or buckets/bowls;
- collecting bottles for sampling;
- disposable plastic gloves;
- microscopes for looking for living material;
- colorimeter if available;
- guides/keys for identification (see especially the Field Studies Council *Freshwater name trail* – see websites).

Points to note in risk assessment

How likely are people to fall in the pond? Is there safe access? There is a very small risk of Weil's disease when using real ponds although a school pond is most unlikely to be affected by rats' urine. Making sure open cuts in the hands are covered with plasters, disposable plastic gloves are worn whilst handling pond water and that there is effective hand-washing afterwards are wise precautions in any case.

Learning outcomes

Students should gain:

- an appreciation of the effect of abiotic factors on ecological change;
- awareness that freshwater organisms are dispersed to new habitats;
- an understanding of succession based on an example that they have seen for themselves.

Case study 2: Succession plots

In this study, small areas of land are cleared of vegetation and observed over a number of years so that succession can be described.

In most schools it is important to discuss the selection of a suitable patch of ground to be left untended with the senior management team and the ground staff, and to gain their agreement. A sign explaining the purpose of the plots is not only informative for other students and parents, but emphasises the serious scientific nature of the work (Figure 2).

Curriculum slot

A-level biology (ages 17–18, optional in England and Wales).

Figure 2 Succession plots.

Much can be achieved with quite a small experimental area. In this case study-plots of one square metre were used. In 1999, 16/17 year-old students dug and cleared two plots, one on either side of the science block. Each year since then another plot has been added, resulting in a series of plots on one side of the building, ranging from 0–7 years old and two plots, both 7 years old, on either side of the building. Corner markers (white painted posts) show clearly the plot boundaries and the gardeners mow round the plots.

Planning and procedure

Students need help with species identification. Pressed leaves and flowers collected and named in previous years are useful as reference material. The fold-out identification charts available from the Field Studies Council (see 'Resources') may prove particularly useful.

Select an appropriate method of recording quadrats, such as percentage frequency, percentage cover or individual counts. Individual counts can be used to calculate diversity indices. To make fair comparisons, as far as possible recordings should be made at the same time each year. We have found that the two plots dug 7 years ago continue to be very different from each other, with contrasting indices of diversity. Drawings or photographs to show the distribution of plants can also prove useful. They can be merged using *PowerPoint*, or as acetate overlays on an overhead projector, to show change over time. For further information about field techniques see the British Ecological Society website (see websites).

Our plots have been made and monitored every July when the ground is soft to dig and the weather is usually good. Adding plots each year has extended the study of succession. It was particularly pleasing when three years ago a tree sapling made an appearance in a cleared plot.

Resources

The following will be needed or useful:

- digging tools for new plots;
- pressed specimens from previous years;
- identification guides for recording flora (see especially the Field Studies Council fold-out charts *Grassland plants* (1 and 2) and *Playing field plants* – see websites);
- blank record sheets, listing expected species, could be used each year;
- quadrat frames.

Points to note in risk assessment

Students need to be made aware of the usual garden hazards. Open cuts in hands should be covered by a plaster and disposable plastic gloves. Check that any student who cuts themselves whilst working with soil (very unlikely in this case) has up-to-date anti-tetanus immunisation. Emphasise the need for hand-washing afterwards.

Learning outcomes

Students should learn:

- that ecosystems change over time and respond to the effects of human interference;
- that a cleared plot gradually becomes colonised;
- details of successional changes from an example they have observed;
- to identify common plants;
- statistical recording techniques;
- the importance of long-term investigations to monitor change.

Case study 3: Investigating pollution using lichens as indicators

Lichens have long been recognised as very good bio-indicators of air pollution. They have been used, for example, to indicate levels of pollution in national parks (Fogel, 1998). Lichens are particularly sensitive to sulfur dioxide, though different species differ greatly in their response to pollution. Roughly speaking, the cleaner the air, the more lichen species are present.

Even rural areas in, for example, parts of the UK may have a very limited lichen flora because they are downwind from large industrial conurbations. The common lichen *Lecanora conizaeoides* is one of the most tolerant species and may be the only one to be found on the surfaces of tree bark and buildings in the centre of some large towns. On the other hand, in unpolluted parts of Western Scotland, Wales and Cornwall lichen growth on stones, buildings, fence posts and trees may be profuse and demonstrate impressive biodiversity.

Curriculum slot

The work described in this case study was carried out as an individual project by a student in the final year of her A-level biology course (an option in England for ages 16–18 year-olds) but the idea could be readily adapted for use with other age groups.

Much may depend on substrate – what the lichens are growing on. Calcareous rock, such as limestone, including that used for making buildings or gravestones, tends to neutralise the effects of acid substances; such surfaces may therefore have more lichen species growing on them than is the case on adjacent types of rock. Similarly, concrete and mortar may have more lichens than adjacent bricks or sandstone.

Some places are more suitable for this activity than others. This case study was carried out in Bath where the general level of atmospheric pollution is low enough, and the local stone sufficiently calcareous, to permit a reasonable lichen biodiversity; this made it a very suitable place to carry out this study. In at least some large industrial cities the lichen flora may be so limited that, whilst there is always a lichen story, it may not offer enough scope for motivating work. Even so, there could be an interesting situation in a graveyard where a variety of materials have been used for headstones. Headstones also have the date when they were erected conveniently chiselled on them.

Planning and procedure

This activity lends itself to open-ended enquiry. The teacher can introduce some general ideas and then invite individual students or groups of students to plan their own investigation. Two areas to be investigated need to be identified: one could be a car park where some pollution might be expected; another could be an area of school where cars do not go.

Record lichen percentage cover by using small quadrats. Acetate sheets with grid lines drawn on and mass-produced by photocopying are flexible and work well for uneven areas such as walls and tree trunks. A useful way of measuring the surface area of a crustose lichen is to trace it on to an acetate sheet (with a suitable pen) and calculate the area by placing the acetate on graph paper and counting squares. Different areas of the wall or tree can be sampled using random numbers generated on a calculator.

The expectations you have for lichen identification will depend on the nature of the students, the site, the investigation and your own lichen identification skills. In some investigations it may be quite enough just to distinguish between lichens, algae and stone/bark. In some cases there may be a good story in comparing the distribution of yellow, green and grey lichens. Again, the handy fold-out identification charts published by the Field Studies Council (see 'Resources' opposite) may make identification easier than you expect. If air pollution has reduced the lichens in your area to just a few species but these species happen to look different, then for once low biodiversity has educational advantages!

Many lichen species do not have English names and their Latin ones can be a bit of a mouthful. The class could agree on suitably meaningful English nicknames, but don't underestimate your students' fine-feature differentiation skills. With hand lenses on a piece of string around their necks, the unlikeliest students may be transformed into self-styled experts. It's an exciting moment when someone says '*Hey – I reckon there are two different sorts of this grey lichen*'. Try *not* to respond by saying '*Oh, just call them all grey ones and get on with it*', but ask whether the students can decide on a simple way of distinguishing them. Of course, if we start to distinguish the grey ones as our skills improve half way through the task, do we have to start the data collection again? What if the two grey lichens have different distributions – it could be the story we are looking for! These are eureka moments to be treasured. Data collection then passes beyond the slavish following of a comfortable procedure aimed at getting the job finished as quickly as possible. Real scientists learn from experience on the job and sometimes come back next week and do it again.

Students decide which variables they intend to make the basis of their investigation. These may include, for example, aspect, height, type of substrate, amount of shade, degree of exposure, distance from a suspected source of pollution.

Resources

The following will be needed or useful:

- some photographs (e.g. Figures 3 and 4) of previous work as stimulus material;
- hand lenses;
- simple colour identification guide (see especially *Lichens and air pollution*, *Churchyard lichens* and *Lichens on twigs* produced by the Field Studies Council – see website);
- measuring tapes – to make gridded areas for sampling;
- calculator – to generate random numbers;
- sheet of acetate (0.2 m^2 with grid drawn on with 1 mm squares);
- graph paper;
- pens suitable for writing on acetate.

Risk assessment

This can be prepared by the students, either through group brainstorming and a flip-chart or by students working individually. Either way the teacher remains in the position of responsibility and needs to make sure that the students' risk assessment is adequate before starting. He or she will have already carried out a risk assessment specific to the particular situation and selected sites that are relatively non-hazardous. In this case study the site in the school grounds was relatively non-hazardous, although the requirements for supervision of students working at the other site (Bath city centre) were much greater.

Outcomes

The student who carried out the investigation that forms the basis for this case study used two limestone walls with the same aspect; one was in the centre of Bath and the other in the school grounds about 1 mile from the city centre. Her results revealed dramatic differences as can be seen in Figures 3, 4 and 5.

More general learning outcomes include:

- awareness of lichens as living organisms;
- use of organisms to monitor pollution;
- appreciation of the extent of (unseen) pollution;
- effect of pollution on biodiversity;
- fine-feature differentiation and identification skills;
- statistical approach to data collection;
- practical use of living organisms as pollution indicators;
- development of investigative skills.

Figure 3 Lichen on a wall in the centre of the city of Bath (photo taken by student). Very few lichens were spotted. There are one or two yellow ones to bottom right of picture.

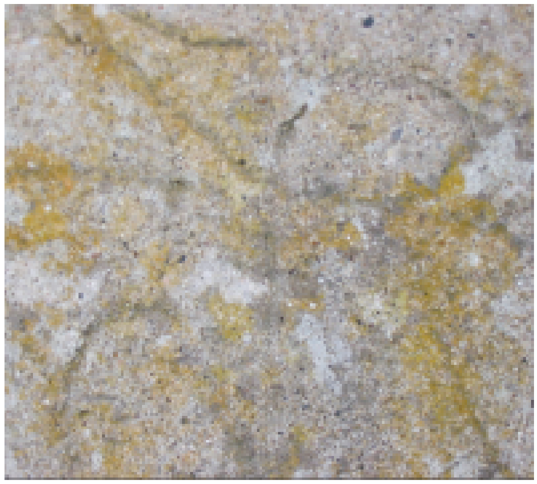

Figure 4 Lichen on a wall, the same aspect as Figure 3, but in school grounds about 1 mile (1.6 km) out of Bath city centre (photo taken by student). Large areas of yellow lichen can be seen.

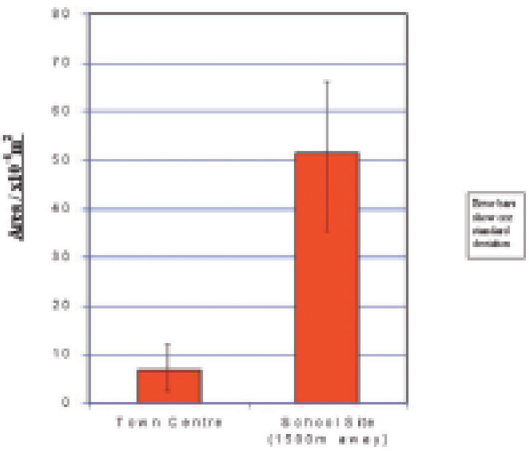

Figure 5 Student's graph comparing lichen cover in Bath city centre with that on a similar substrate of a similar aspect one mile (1.6 km) away.

Discussion

Outdoor biology has a well-established tradition in the UK and it has for long embodied a great deal of what is now regarded as good practice in science teaching. It has always tended to be hands-on, investigative, inspirational and motivational. It has always involved teamwork and lent itself to a student-centred approach, and it nicely marries together scientific knowledge and understanding, practical skills, and a statistical approach to data collection. It offers inspiration, open-ended enquiry and a wider educational context, which includes issues of sustainability, citizenship and the environment. It also demonstrates how scientific knowledge can enrich one's enjoyment of the world in which we live.

References

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QCA (Qualifications and Curriculum Authority) (2004) *Science: the National Curriculum for England*. London: HMSO.

Websites

The British Ecological Society (BES):
http://www.britishecologicalsociety.org/
Offers a teacher's toolkit of grants to support good practice in ecology teaching including support for developing school grounds, equipment and professional development, and has a developing outreach programme in collaboration with the Field Studies Council.

The Fieldwork Knowledge Library:
http://www.fieldworklib.org/
Provides a comprehensive guide to fieldwork for teachers including basic techniques, how to organise fieldwork, how it can fit into the curriculum, case studies, websites and advice on health and safety, with separate sections for biology, chemistry, physics and earth science organised according to key stages 1 to 5 of the English National Curriculum. Developed by the London Science Learning Centre with funding from the DfES in 2005, it is now maintained and continuously developed by the British Ecological Society and the London Science Learning Centre. Also accessible from the BES website (see above)

The Field Studies Council (FSC):
http://www.field-studies-council.org/
Environmental education charity committed to the promotion of outdoor science, offers a range of useful publications and professional development to support the teaching of ecology. As well as providing residential and day courses for schools at its own centres throughout the UK it supports outdoor science organised by teachers in or near school grounds through an outreach programme in collaboration with the BES.

FSC guides/keys:
http://www.field-studies-council.org/publications/foldout.aspx

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