Practical work and the importance of scientific evidence in science curricula

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Introduction

Stimulated by the call for evidence on behalf of SCORE (see page 7) requesting views on practical work in science, this article responds to some frequently asked questions with reference to science teaching in compulsory schooling to GCSE (up to the age of 16).

Background and assumptions

Science is primarily about ideas, not facts or skills, and those ideas must be the fundamental ones without which the edifice cannot sustain itself. Practical work should be seen as a means to that end, rather than an end in itself.

The predominant view of science is one that speaks of exactness. Failures to predict precisely the result of global warming, for example, are then seen as failures of science, or scientists. There is an increasing danger of a pre-enlightenment view of the world, where intelligent design and 'quack' medicine are afforded the status of 'alternative science' when in fact they are, by definition, not science at all, being either untestable or adopted in the face of evidence to the contrary, or both.

Practical work has a critical part to play in addressing this. It should be the vehicle through which students come to appreciate that science is not exact – not because of our failure, but because modelling nature is a fascinating, if extraordinarily difficult, task. It is the very simple fact that measurements are not easy to make. Think of the way global warming models depend on measurements of sea temperature and the difficulties in deciding which sea, when, how deep and so on. The uncertainty associated with this measurement can have a critical effect on the extrapolated slope of global temperatures. This is the sort of understanding that we must place at the centre of our approach to science.

Practical work is an important way into this argument. If students understand the problems of measurement at first hand, and the effects that uncertainties have on conclusions, and if they can see how evidence is used to structure a scientific claim, hedged around as it is with qualifications and 'error bars', then they will be better placed to come to a sound, critical but realistic view. That should be our task. But, how can it be achieved and is there any evidence as to its efficacy?

Having collected data, students should be involved in developing a claim based on that data (Gott & Duggan, 2007). This claim will involve them in weighing their evidence carefully, and qualifying and delimiting it. We see this as essential in that it will develop an understanding of how claims link to the underlying evidence base, and hence develop the sort of critical but open approach to the claims of others.

In summary, we see practical work as contributing to an understanding of:

- Basic ideas related to the collection, analysis and interpretation of evidence;
- How that evidence is weighed in the balance in the process of making a scientific claim; and
- How the scientific claim is structured and delimited and how that understanding can develop a real scientific literacy, which is forensic and empowering rather than explanatory and patronising.

In addressing the questions below we argue that such an understanding is necessary to combat the rise of anti-scientific 'mumbo-jumbo' that passes for reasoned debate at all levels of society and which is threatening its rational base.

What do you consider practical work to be?

This question could be read as implying that practical work is an end in itself. It is so for the intending scientist or engineer perhaps, but not for the majority, for whom we must see it as a way, amongst others, of teaching ideas. It may involve hands-on activity with real objects and materials in the laboratory and outside in the field, but always with a view to understanding an idea; an idea, we would argue, related to the quality of any evidence rather than the substantive issue. It may bring with it additional benefits in terms of motivation and practical skills, but in the compulsory years these are to be seen as a bonus.

We take the view that 'practical work' is a somewhat misleading term, which fails to encompass the ideas that underpin practical science. It suggests activity in the presence of equipment and labs and so on. We suggest it is better to focus on what is to be learned through the activity:

- Observing objects and events through scientific spectacles, thereby identifying key features for future investigation, and uncovering the conceptual framework through which the observation has been made.
- Designing and carrying out experimental tasks (but not simply following recipes) with understanding of the key evidential ideas.
- Analysing and interpreting the resulting data.
- Constructing a claim in which the data is weighed as evidence and suitably qualified as appropriate.
- Developing a critical approach where data is seen as a non-negotiable necessity; *nullius in verba* – the Royal Society's motto, loosely translated, as *'take nobody's word for it'*.

Can parts of investigations be taught through the use of secondary data via the Internet or simulations?

Once we see the purpose of practical work as being a teaching method for understanding ideas about evidence, then the type of practical work is a pragmatic one dictated by the circumstances, and an empirical one; does it work better than another method? However, we believe that there is no substitute for putting these ideas into practice (doing some joined-up thinking) in open-ended investigations, where the pupil does not know the answer to the problem, where there are different 'routes' to the solution, where data is 'messy' so pupils need to make their own decisions.

Data from the Internet and other sources are useful but, from experience, it is very hard to get hold of messy raw data and enough information about the design, instrumentation, etc., to be able really to understand and use it sensibly. Most available data from the Internet is 'cleaned' and there is a tendency to use it to illustrate the substantive ideas, rather than looking at the quality of the evidence itself. This is true of many computer simulations; they are substantively driven with limited data, or data generated to 'prove' the underlying theory. There is also the problem of `screen culture', where airbrushing is seen as the norm, hence the crucial importance of collecting one's own data.

How important is practical work in science education and why?

We believe it to be important, but not in its current format which, driven by the reductionist and debilitating National Curriculum, is a waste of time (House of Commons, 2002). It must be designed for its particular purpose – raising awareness, consolidating an idea, teaching about observation, teaching ideas about evidence, giving pupils an opportunity to make their own decisions in investigations, and so on. Then it can be motivating and pupils can work at their own level, i.e. work is differentiated by outcome.

Good practical work out of the classroom does all these and introduces pupils to 'messy' data, which is vital to their understanding of how science works and why it is possible for scientists to qualify their predictions and disagree amongst themselves. After all, most science they come across in their adult lives is 'messy' and much is related to environmental issues. Fieldwork teaching, in particular, tends to articulate ideas about evidence well; how to sample, how to handle repeated/varied data, how many repeated readings, comparison of different measuring methods and using statistics to summarise varied data.

What do you consider are the current and future opportunities and barriers to high quality practical science in schools and colleges?

Current practice to GCSE level is in many cases sterile, driven as it is by the high-stakes assessment that is putting off intending scientists as schools vie for league table rankings. The science curriculum is one designed by committee, with little underlying clear rationale, full of vague good intentions, but lacking in the sort of self-confident approach that underpins the inspiring teacher.

How could the government and its agencies strengthen good quality practical science in schools and colleges?

- Immediately scrap the National Curriculum assessment below GCSE (the SATs);
- Revive the professionalism of teachers by allowing them to be creative;
- Disentangle much of the language in curriculum documentation; the term 'practical work' is used indiscriminately, to cover all sorts of activities with different purposes. Also, other terms such as 'processes' and 'Nature of Science' are so vague that they are open to almost any interpretation;
- Create a content-rich evidence-based curriculum (alongside, of course, a slimmed-down set of basic ideas in physics, chemistry and biology), providing a wide variety of practical and non-practical tasks from which to draw out ideas about evidence, how to progress to a more sophisticated understanding and how to structure and de-construct scientific claims; and
- Good quality INSET should be made available.

References

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