Children from Remuera Primary School, Auckland, New Zealand, involved in exploratory activities whilst investigating sound

ENQUIRY AND GOOD SCIENCE TEACHING

Wynne Harlen discusses the meaning of enquiry in science and why it is the appropriate way to learn to be scientific

The word *enquiry* (*inquiry* in the rest of the world!) has been taken up with enthusiasm across the curriculum as well as in science education. It is not new in this context (what is?), having occurred frequently in the writing of Dewey in the early twentieth century and often used by early pioneers of primary science. For instance, Nathan Isaacs (1960), in one of his most compelling essays, refers to children's '*inquiries*' and to the '*attitude of science inquiry*'. These writers used the word, however, almost interchangeably with '*investigation*' or '*exploration*' and did not attempt to define it. More recently it has been used as if synonymous with 'hands-on' or active learning, as in the NFER report for NESTA (NFER, 2008).

Now that prominence is given to scientific enquiry and enquiry skills in national curricula we need to be clear about what is meant. Moreover, worldwide, there is enthusiasm for changing from traditional science teaching where facts and principles are taught didactically to enquiry-based science education (known internationally as IBSE). The implications of this change for teachers, resources and pupils are immense and the expense needs to be justified. So evaluating the impact of IBSE is important, but first we have to know what it is and what is different in classrooms where enquiry is being implemented.

Box 1 A definition of enquiry

Inquiry is a multifaceted activity that involves: making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 1996: 23)

The definition in Box 1 is widely quoted. It fits in well with our view of the importance of 'active' learning, meaning mental as well as physical activity. It is quite comprehensive and allows the possibility of different kinds of activity that can be called enquiry. For instance, the new National Curriculum for Wales refers to different types of enquiry, such as pattern-seeking, exploring, classifying and identifying, making things, fair testing, using and applying models. For the curriculum in England, the DCSF Standards Site lists six quite similar types of scientific enquiry.

What makes enquiry scientific?

But take another look: where does the word 'science' or 'scientific' appear in Box 1? The processes listed there can be used in many other subjects as well as science. What is it that makes enquiry scientific and different from enquiry in mathematics, geography or history education? One answer must surely lie in the subject matter. Scientific enquiry is the deployment of enquiry skills in striving to make sense of events and phenomena in the natural and made world around us. This endeavour is stimulated by questioning, and the investigation of possible answers based on initial ideas. This may involve experiment, careful observations, consulting secondary sources or discussion about the problem or event.

Even when the subject matter of the activity is a phenomenon or event in the natural or made world, the enquiry may not justify the label of 'scientific enquiry'. This may well be the case when, despite being active, the children are not developing ideas from evidence, but are being told the answers to what happens and why. In other words, there may be lots of action – observing and recording, even predicting – but not much use of the skills that engage their minds and develop their understanding. What is missing then is the scientific thinking that uses evidence to test ideas. These may be initial, non-scientific ideas that children have developed from everyday experience, or the beginnings of theories that may eventually become 'big' ideas. This is the crucial element that distinguishes 'scientific enquiry' from enquiry in a more general sense.

Scientific enquiry in action

Box 2 contains part of a discussion between two children and their teacher during an investigation of the different behaviour of three hen's eggs, labelled A, B and C, when put in tap water or in salty water. They knew that one was hard-boiled, one soft-boiled and one raw. They had to find out which was which. The emphasis was on observation, making fair comparisons and interpretation, since the situation was set up for them.

Notice how Allyson develops her ideas using her existing knowledge about how the inside of the eggs affects their behaviour (good eggs sink, bad ones float) and tests her hypothesis with the evidence. Meanwhile Deidre is paying particular attention to the different behaviour of one egg in the tap and salty water. Both are using evidence from the things in front of them to test ideas and make inferences that would explain the behaviour of the eggs. The teacher supports this thinking by probing their reasons for their claims.

Contrast this with a lesson in which groups of 9-year-olds are given clockwork toys and asked to measure how far the toys travel for different numbers of turns of the key, and a table in which to record their results. After the action they report that the more turns of the key, the further the toy travels. They probably knew this already from their experience of such toys. But they may not have known why and the explanation is the main point of this lesson. The teacher then proceeds to explain the reason, involving the children only in answering leading questions such as '*Does it take more energy to go one metre or two metres?*' There is plenty of action here but it is not the basis for testing or developing ideas.

Enquiry as development of understanding

This leads us to a key function of enquiry: to develop understanding. So, to quote another definition, *scientific* enquiry is the development of '*understanding of fundamental scientific ideas through direct experience with materials, by consulting books, other resources, and experts, and through argument and debate among themselves. All this takes place under the leadership of the teacher*' (NSF, 1997: 7).

This definition recognises that enquiry does not always involve materials and objects that children can actually handle and/or manipulate. The apparent movements of the Sun, Moon and stars are not susceptible to

Box 2 Understanding the behaviour of eggs (from Harlen and Qualter, 2009)

Teacher [joining two girls after they had been working alone for some time]: *Can you tell me how you are getting on?*

Deidre: *I think that C is raw.*

Allyson: *We both think that C is raw.*

Teacher: *Do you?*

Deidre: B is ...

Teacher [to Allyson]: *Why do you think that?*

Allyson: *Because when you put eggs in water bad ones rise to the top.*

Deidre [at the same time]: *Because it ... we put them all in ...*

Teacher: *Bad?*

Allyson: *Yes, I think so – or is it the good ones? ... well, I don't know.*

Teacher: *Yes?*

Allyson: *They rose to the top, so ...*

Deidre [putting the eggs into the salty water]: *That's the bottom* [pointing to C].

Allyson: *If it's raw it should stay at the bottom.*

Teacher: *I see.*

Deidre: *So that's what we think. C is raw and B is medium and A is hard-boiled.*

Allyson: *... and I think that B is hard-boiled and she thinks that B is medium.*

Teacher: *Ah, I see.* [To Deidre] *Can you explain, then, why you think that?*

Deidre: *If we put ... er ... take C out* [takes C out, puts it on the table, then lifts A and B out] *and put these in, one after the other. Put A in – no B first. That's what ... Allyson thinks is hard-boiled, I think it's medium. If you put that in ...* [she puts B into the salty water].

Allyson: *...'cos it comes up quicker.*

Deidre: *It comes up quick. And if you put that in ...* [She puts A into the salty water. It goes to the bottom and rises very slowly.]

Allyson: *And that one comes up slower.*

Deidre: *So, I think that one* [pointing to A] *is hard-boiled because it's ... well ...*

Allyson: *I don't. I think if we work on the principle of that one* [pointing to B]. *Then that one comes up quicker because it's, you know, not really boiled. It's like a bit raw.*

controlled investigation but they can be studied by careful observation, and understood through the use of models or the interpretation of findings in relation to different theories or ideas. Secondary sources can also be used to provide data for testing hypotheses. A good example of this was described in *PSR* **40** (Govier, 1995), where children used a CD-ROM of images of many different animals to test their hypotheses about why some mammals have forward-facing eyes and others side-facing eyes. So not all learning in science is through enquiry. There are procedures, conventions, names and basic skills of using equipment, which are best taught directly as and when they are needed. But when the development of understanding is the aim, enquiry is the appropriate way to learn.

The importance of scientific enquiry is supported by the DCSF on the grounds that it '*has a central place in science because it helps pupils to understand how scientific ideas are developed and because the skills and processes of scientific enquiry are useful in many everyday applications. Scientific enquiry provides opportunities for pupils to consider the benefits and drawbacks of applications of science in technological developments, and in the environment, health care and quality of life*.' Primary teachers in the 2008 NFER survey for NESTA provided wide support for this view.

More than enquiry?

So enquiry is more than the use and development of skills; more than first-hand learning; more than active learning. But does it comprise the whole of what we might call 'good practice' in science education? There is nothing in the definitions of enquiry quoted earlier referring to starting from children's ideas or about learners being involved in self- and peer-assessment (and other features of using assessment for learning). Where do these key aspects of good practice come in? There are those who would bundle assessment for learning and constructivism into an expanded concept of enquiry. To my mind this overburdens the concept and makes it more difficult to maintain focus on the development of scientific understanding. Rather it seems better to see these as referring to different aspects of learning and teaching:

- **Enquiry** as a view of what learners and teachers need to do to develop understanding (in science).
- **Constructivism** as a view of how learning takes place that guides decisions about learners' and teachers' actions.
- **Formative use of assessment** as an approach to teaching that identifies and promotes progression by matching challenges to children's ability to meet them.

These aspects have a good deal in common: for learners, learning actively, mentally and physically, and reflecting on learning; for teachers, making provision for active learning and discussion.

However, each contributes important elements to good science teaching:

- **Enquiry** contributes the attention to skills and the collection and use of evidence in testing ideas.
- **Constructivism** adds the recognition of the importance of the ideas that children develop for themselves from their experience and interaction with others and of the use of these ideas in teaching.
- **Formative use of assessment** adds the importance of pupils knowing the goals of their activities, taking part in self-assessment and deciding their next steps and how to take them; and of teachers providing feedback that helps learning.

Conclusion

Enquiry is an important concept in science education, describing the way in which process skills (now more usually called enquiry skills) lead to understanding. The key feature of scientific enquiry, as opposed to more general enquiry, is the use of evidence from the natural and made world in testing ideas about how things work. Often, but not always, this evidence is derived from first-hand manipulation of materials or direct observation of events. In helping children to make sense of the world around them, other features of their learning experience are important, in particular starting from their existing ideas and using information about their progress to adapt teaching and the pace of learning to ensure understanding. So the term 'enquiry-based science education' is useful in signalling that there are other aspects of good science teaching in addition to enquiry.

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