

# Science now and then: discovering *How science works*

James Williams, *Special issue Editor*

In September 2006 a new programme of study for science at key stage 4 (ages 14–16) came into effect in England and Wales. This September sees the introduction of a new programme for key stage 3 (ages 11–14). The underpinning feature of these much-shortened programmes is what has been termed *How science works* (HSW). New GCSE, AS and A2 specifications have been produced and ratified by the Qualifications and Curriculum Authority (QCA) that aim to present science content within the HSW framework. In its guidance to schools, the QCA explains *How science works* as being:

*sometimes referred to as 'science process'. It includes scientific method and the way scientific knowledge develops. Developing ideas and theories lies at the heart of science. 'How science works' focuses on the evidence to support or refute these ideas and theories. (QCA, 2006).*

What is lacking however is a coherent and generally accepted view of exactly what is meant by HSW. QCA provides little to no background guidance for teachers and the examining bodies seem to have settled for various interpretations of HSW, mainly, but not exclusively, related to the experimentation and investigation model that science teachers have been using for a number of years. Some things have changed, such as a proliferation of defined terms related to practical skills. Up and down the country pupils are learning the difference between 'precision' and 'accuracy', 'reliability' and 'validity'; teachers have also undergone a steep learning curve, adopting and introducing these terms into their lessons. Is this really *How science works*? Is that all there is to the new process-led curriculum?

There is clearly a need for a coherent model for HSW, even if it is just to stimulate discussion with the aim of coming to a consensus – not that science is famed for its ability to easily come to

such a view. So here I propose, in brief, such a model (Figure 1). At the heart are three spheres of functional and historical science: *Argumentation*; *Experimentation and Investigation*; and *History and Philosophy of Science*. They all overlap to some degree and scientists working in different disciplines will identify themselves more closely with one or other of these spheres. The outermost enveloping sphere simply shows that this is how scientists work. Whatever their discipline, scientists will use skills, knowledge and understanding from these spheres to conduct the business of science. If we are to teach HSW effectively we must also deliver a science curriculum that exemplifies and illustrates these spheres. Simply delivering experimentation and investigation, for example, results in a deficient model of HSW.

In this edition of *School Science Review* we offer some other views of HSW, in particular some of the stories surrounding scientific discovery. The five articles may, at first sight, seem to be contrasting views of how science works, even of how scientists work. But I hope

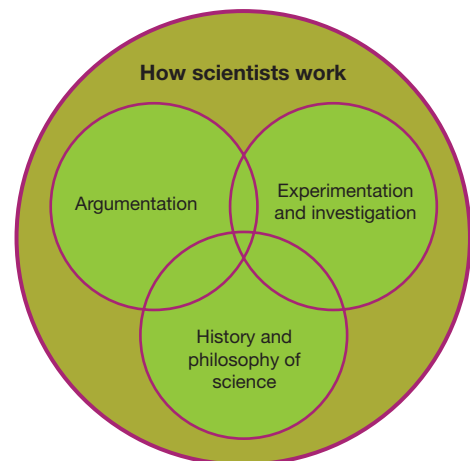


Figure 1 A model for *How science works*

that in considering the above model, proposed as one way of unifying various aspects of HSW, the choice of articles will become clear.

Science is, at its simplest, the acquisition of knowledge. Scientists have, over thousands of years, developed ways of working that promote laws and theories as descriptions and evidenced explanations of natural phenomena. HSW could easily have been labelled '*How scientists work*'. Exactly how a theoretical physicist, an astronomer, an industrial chemist, a geologist or an environmentalist works will vary considerably, regardless of whether we compare historical accounts of their work to contemporary practices or compare different scientific disciplines with each other today.

Grace and Hare (p. 47), for example, provide us with a view of how environmental scientists work and how they construct their theories within socio-economic and cultural frameworks, leading some to question whether conservation science is a science at all. With value-laden judgements, conservationists, unlike many chemists and physicists for example, cannot operate in a value-free way. Looking at how conservationists work, they argue, is a good way of addressing many aspects of moral, spiritual, ethical, social, cultural and citizenship aspects of the curriculum.

In contrast, Kosso (p. 53), in an informative historical article, looks at the story of the discovery of Neptune, which highlights the logic and limitations in testing a scientific hypothesis. Astronomers cannot perform 'experiments' in the conventional laboratory sense. Their observations, induction, deductions and inferences are tests of logic that fall into philosophy and argumentation more readily than, say, an industrial chemical process. Science, Kosso says, is not about 'absolute truth'. He argues that while science may sometimes deliver 'the truth', what it cannot deliver is absolute certainty in that truth. We may regard ideas and discoveries in science as 'true' in the context in which they were discovered; what we cannot claim is absolute certainty for these claims – that they will not be contradicted at some future point.

Hutton (p. 59) outlines the work he undertakes with trainee science teachers, work that can easily be replicated for practising teachers. Posing

questions about the nature of science and the scientific method, using quotations from historical and contemporary scientists about how they work, he encourages his trainees to learn about HSW from what scientists actually say about the way they work. The article encourages trainees, and teachers, to think not just about the science or the discovery, but also the context within which discoveries are made. Looking at the lives of scientists, Hutton argues, provides not just insights into the scientific method, but also brings a dimension often lacking in science teaching – the human face of science.

In her article outlining the discovery of insulin, Essex (p. 65) brings to the fore the human side of science. By tracing the development of successive formulations of insulin from animal to human and analogue, bio-engineered insulin, she illustrates how social, ethical and commercial considerations have influenced the development of engineered insulin, even if there is not the scientific 'evidence' to show that these are indeed 'superior' products.

Campbell and Sang (p. 77) describe a resource for teachers. They provide a series of case studies in the history of physics and outline some practical activities, with supporting notes and discussion points, that teachers can use in their classes.

What all the articles in this special theme show, is that the context within which science is 'done' is important. Science is not 'context free'. At the heart of HSW there may be 'pure elements' such as logic, argumentation, strict experimental method, etc., but how scientists work and, de facto, *How science works*, is not context free.

The model proposed here is my model and it is proposed so that it may be adopted, adapted, criticised, even rejected if necessary. It is put forward so that there is at least one coherent view of HSW that teachers can use to frame their teaching. This model is really a starting point. To arrive at a consensus view of HSW, in the context of science teaching today, we must necessarily consider all parts of the model, perhaps even that there is, in reality, no 'scientific method'.

#### Reference

QCA (2006) *How science works*: [http://www.qca.org.uk/qca\\_9437.aspx](http://www.qca.org.uk/qca_9437.aspx) (accessed 20 July 2008).

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