Teaching the nature of science (and keeping students engaged)

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There’s knowing science, then knowing how to teach it. B Rosen

Peter Ellerton

Peter Ellerton is a Friend of The Conversation.
Lecturer in Critical Thinking, The University of Queensland

Last week’s Health of Australian Science report, by the Chief Scientist of Australia Ian Chubb, has again highlighted the issue of declining student engagement in science in primary and secondary schools.

Why are we in this position? One factor is a fundamental misunderstanding, at all levels, of the “nature of science” – no small thing! We’ll get to the nature of science shortly, but first …

Declining student engagement has been a source of angst for scientists and educators for some time, and has resulted in no end of solutions being offered by no end of well-meaning individuals – solutions that include streamlining the entry of practising scientists into schools, paying science teachers more than those of other subjects and improving pre-service teacher education.

Teaching teaching

It’s important to understand at least two things are essential for effective teaching. The first is knowledge of your subject content and processes; the second is general pedagogical knowledge, which is to say an understanding of teaching.

Knowledge of a subject is what you might get out of a degree in a particular discipline; pedagogical knowledge might come from teacher training in the form of postgraduate qualifications or an education degree.

Anyone familiar with the work of John Hattie – director of the Melbourne Education Research Institute – knows how critical, and quantifiably so, a teacher’s pedagogical knowledge is to student success.
The overlap of subject knowledge and teaching knowledge is where we find what is known as pedagogical content knowledge (PCK) – knowledge unique to, or at least characteristic of, a particular subject area.

Obviously it’s a different thing to teach chemistry than music, history than biology, and indeed physics than mathematics. PCK is something that begins in teacher training and is developed by experience in the classroom and discussion with colleagues.

Knowing which teaching techniques work well within your field, how students work with subject-specific concepts in terms of misconceptions and misunderstandings, and how to link and develop ideas as you guide students through a course of study, are part of what defines excellence in teaching.

But there’s something missing here – and it’s a biggie. What’s particularly disturbing about current science education at the primary, secondary and tertiary level is the almost complete lack of explicit consideration of what I’ve referred to as the “nature of science”.

Not only are many teachers unaware of the nature of science, they would have little idea how to teach it in detail even if their knowledge was developed.

This is a contentious claim, but it is supported by research and certainly matches my experience of teaching science in state and private schools over many years.

Nature of science

I mean something very specific by the term “nature of science”, as the following points will hopefully illustrate:

it’s about the philosophical and practical understanding of the processes and reasoning of science, including its nature as a very human endeavour

it’s knowing what the difference is between hypotheses, laws and theories (and how most science textbooks get this wrong) and what the characteristics of a good hypothesis are

it’s about how the structures and processes of science are the way they are, in large part, to account for our cognitive biases, and that unique subjective experience is not foundational in science as it is in other areas of knowledge

it’s about knowing that there is no one scientific method, but that there are many scientific methodologies and that what makes an idea scientific is the goal of maximum explanatory and predictive power combined with exquisite falsifiability

it’s understanding that solid scientific ideas have many defined parameters – the more the better - and that this is what separates them from pseudoscience, where goalposts are constantly shifted (ever seen a psychic renege on a promise to read minds because the presence of a sceptic is “disrupting the energy”?)

it’s being able to explain the difference between induction and deduction, to characterise and instantiate the types of inferential reasoning that are acceptable in science and what problems and opportunities this presents in public understanding
it’s realising that the search for certainty in much of science is a fool’s game, but to ignore levels of confidence makes you a bigger fool.

Thinking critically in science means, in large part, to be able to do such things.

**Moving forwards**

All the above and much more can be articulated and taught alongside traditional science content but hardly ever is. The pressure of content-driven standards, in which factual content is pegged out to signpost progress and the learning of which is the key indicator of success, is overwhelming and simply crowds out what are seen as less quantifiable aspects of science.

Even experimental work is all too often prescribed via worksheets that lay out methods to follow and hypotheses for testing that leave little room for serious reflection, imagination or understanding.

Some (many) even contain phrases such as “has the hypothesis been proved?”, which shows a miserable understanding of the nature of experimentation.

So discussion in classrooms about the nature of science is scarce because:

1) the nature of science is not well understood by science teachers or even scientists

2) the clear implication that without content knowledge in the nature of science there can be no pedagogical content knowledge

3) science curricula rarely articulate exactly what skills or knowledge are constituent of an understanding of the nature of science.

The Australian Curriculum has developed what it calls General Capabilities (GCs) in Critical and Creative Thinking, which are quite well presented but in very general terms.

How they link to what is a very ordinary content-based structure is indicated by an icon – and that’s it. There is no detail given and no guidance for developing PCK outlined, and no sense of how these GCs are to be understood or delivered.

Teachers need assistance to ask and answer pointed questions. How do you teach about the nature of science? What are the techniques, strategies, opportunities, unique mental processes to be aware of and best examples to do this within a curriculum that does not acknowledge its importance, as many do not?

This is a difficult challenge, and an important one, as it is very often these themes that students find engaging and which provide a narrative to their experience of science. It is almost farcical that these are seldom explicitly outlined in programs of work.

Knowledge of the nature of science is as least as important in creating scientifically literate citizens as factual content knowledge – perhaps more so.
Few of us can claim a deep knowledge of all the scientific knowledge relevant, indeed critical, to our lives. But at least through knowing something of the nature of science we can appreciate the epistemic credibility of what comes out of scientific inquiry.

The Health of Australian Science report laments that students are bored with, and do not see the relevance of, science. Conversation revolves around availability of teachers and delivery of standard courses, and curriculum design remains driven by factual content.

Meanwhile, the potential to create more engaged, scientifically literate students who themselves might be more inclined to teach and communicate science sits relatively untapped.

We should change that – and soon.