Re-imagining science education: Engaging students in science for Australia’s future

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Overview

In late May an issue of the Australian Education Review (a publication of the Australian Council for Educational Research) was released, dedicated to a review of Science Education in Australia. The review attracted quite a bit of media interest, because it argued quite strongly that we are in the advanced stages of a crisis in school science that threatens the future of Australia as a technologically advanced nation, and we need to change the way we think about the purposes and practice of school science — we need to re-imagine it — if we are to turn this crisis around.

I was invited to write that review to follow up the ideas from a conference run by the ACER in August 2006, in which international and national speakers spoke about ways forward for school science. At the final plenary session there was strong support for the notion that we need to re-imagine science education. The papers from that conference can be found at http://www.acer.edu.au/research_conferences/2006.html and the report itself downloaded from http://www.acer.edu.au/news/.

In the review I argue that we need to develop a new and fresh approach to school science if we are to recapture the imagination of students and do justice to the enormous range of ideas and practices of contemporary science. We cannot turn the situation round by simply refining traditional school science practice. However, there are many successful examples of innovative practice here in Australia we can draw on to find a way forward. Nevertheless, what I am advocating is challenging both for schools, school systems and the broader community, and if accepted and acted upon, will take some time and effort, and some rethinking by curriculum and resource writers, and by us as teachers of science.

The crisis

The position taken in the review gathered wide support. The deep concern by governments and by educators about falling numbers of science students at all levels beyond the compulsory years, the current and looming shortage of teachers of science, particularly in rural areas, the predicted shortfall in science trained professionals, and the many studies that show that our students in years 7–10 do not find science as compelling as other subjects — all these are well established as the dimensions of the crisis. If you read Geoff Masters’ presentation at the conference showing that the percentage of the year 12 cohort in biology, in physics and in chemistry in 2002 was less than half that in 1978 in each case, you would recognise the magnitude of the crisis. If you were to read a series of major government reports from Europe, the UK, the USA and Australia calling for concerted action on this, you would appreciate the concern at the highest levels about this flight from science. In fact the crisis was predicted decades ago, but policy and curriculum inaction has led to the situation we now face.

In the review I link these strands together to argue we are faced with a downwards spiral that needs arresting. I also identify the cause of this malaise in science education as linked to the nature of post-industrial societies. Results from the international ROSE (Relevance of Science Education) project show a remarkable strong negative correlation between students’ response to science and their nation’s developmental index. The less developed a country, the more its students like science. I argue that the way science is practised and the way it links with modern society has changed fundamentally since the basic shape of school science was set down.

Also, young people coming through secondary education are very different now to the faithful consumers presumed by traditional school science. There have been some interesting studies showing that they are no longer willing to subscribe to the notion of a single pathway through their lives. They respond to the complexity and uncertain future characterising life in contemporary technological societies by demanding flexibility in their education and focusing on the development of skills that will proof them against uncertain job markets. A science education focusing exclusively on concept acquisition, delivered largely through transmissive pedagogies, does not stack up against the ideal of involving students actively in their learning, focusing on a range of skills and capabilities that provide flexibility and purpose for learning, and a sense of control over ideas.

A review of a number of interview studies of student attitudes to science, by Terry Lyons from the University of New England (Lyons, 2005), including his own, identified a number of key themes in what they were saying, namely:

- a transmissive pedagogy that characterises school science
- decontextualised content that does not engage students’ interest or commitment, and
- the unnecessary difficulty of school science.
Terry Lyons' study was of high achieving students and he found that even these students were disenchanted with their school science, echoing findings from a Swedish study that identified students naturally interested in science outside school, choosing against science studies.

What we need to do is to shift the focus of school science away from the rehearsal of resolved concepts, towards science ideas being explored as powerful and flexible tools with which to explore and interpret phenomena, particularly in situations that are meaningful to students and that link with their social and imaginative lives. At the ACER conference teachers argued enthusiastically that science needs to be taught in context and link with students' lives and interests, and gave many examples of such approaches. There are many examples in projects I have been involved with, of teachers engaged in curriculum innovation on the basis of their own scientific interests. This is the case for a number of schools who teach chemistry through winemaking, for instance, or are engaged in community based environmental projects. The other part of the story is that students need to be skilled in ways of thinking and working scientifically, in the context of science as it is practised in contemporary society and is experienced by citizens.

To follow the implications of this argument requires a big shift in thinking and some people respond by suggesting that we are downplaying the importance of the mastery and display of disciplinary knowledge. This is not so. Knowledge is of course important, but we need to change the way it appears in our practice as science teachers, and in curriculum and textbook writing. I suggest that conceptual knowledge is only valuable in its use, and if we are to avoid the stranglehold that knowledge structures currently exert over our curricula and our way of looking at science, we need to throw much more energy into representing science as a way of thinking and working; of exploring and problem solving.

The purposes of school science

There has been much written about the ways in which the practice and impact of science has changed in recent decades. Science is increasingly global, competitive and multi disciplinary. Increasingly it is entangled in substantial social, ethical, economic and political issues. It has huge impact on our lives, and citizens engage with science in diverse ways. Science is increasingly being challenged as a thought system by post modern writers, socially critical commentators, religious interests and advocates for culturally diverse groups.

We need to re-examine the purposes of school science, which has to date resulted in an almost exclusive focus on concept building. This focus has been in part a result of not including in debates about school science a broader range of people; people who practice science in industry, people who through their work see the impact of science on the community and on the lives of people. If we are to develop a science to cater for all students, we need a wider range of voices being heard.

In this regard, to explore the nature of contemporary science we ran focus groups of scientists working in six of Australia's research priority areas, including climate change, modern materials and health (Tytler and Symington, 2006). All groups expressed a serious concern for how the public viewed and interacted with science. They argued the need to have a more science-savvy citizenry who could engage in public science issues and debates, and who would be intelligent commentators on technological innovation. With regard to the skills needed by scientists working in the field, these groups tended to emphasise capabilities such as analytic thinking, communication, problem solving, and team work, more than lists of knowledge. Other research also supports the claim that scientists are valued as much for their habits of mind as for their conceptual knowledge.

They made the point that science was universally embedded in social and ethical contexts, a reality which needs to be represented in school science. In these various ways they felt that school science did not reflect the practice of contemporary science.

The term 'scientific literacy' as a curriculum driver refers to the need to develop a school science
that will focus on preparing future citizens for their interactions with science. The sort of science that future citizens will need is not straightforward to predict. Research studies into a variety of ways citizens use science, in personal decisions about health for instance, or in understanding and influencing public science-related debates such as climate change or health policy, or as government or industry advisors or entrepreneurs, have provided useful evidence. Students should leave school feeling comfortable about and interested in science, and willing to engage with science ideas throughout their personal and professional lives. This entails a curriculum emphasis on the methods of science and the nature of science as it works in the world. Conceptual knowledge is important, but it should be situated within this wider purpose.

Thus the purposes of school science need to be re-imagined, and broadened. The content needs to be more open and flexible and geared to developing a wider set of capabilities, including interest, than is currently the case.

**So what might a re-imagined science education look like?**

Firstly, learning is highly contextual and 'concepts'like air pressure or adaptation in real situations involve multiple representations woven into complex explanatory narratives. We all know that 'understanding a concept' is not a matter of being able to rehearse and recite a set text. It is the cut and thrust of using and negotiating ideas in context that is the real intellectual task of science. Thus, a focus on the multiple ways we represent ideas and processes provides a conceptual flexibility that a focus on the rehearsal of pre-packaged concepts does not. The idea of representation in science is discussed in Tytler, Peterson and Prain (2006). Primary Connections, the national program for primary science education, focuses on the literacies of science as a way of supporting learning. A description of Primary Connections can be found in Mark Hackling's presentation on the ACER conference website.

I and a colleague recently worked with Year 7 teachers at one of Deakin's partner schools, on a unit on force. The text book ran through a range of forces and represented them in a variety of ways which were not justified or explained to the readers. As an alternative strategy we decided to approach the problem of force as one of representation and ask students to generate ways of representing contact forces. Over the unit these representations would be negotiated and their value discussed. In discussions of friction (how can we represent frictional forces?) focusing round an exploration of different running shoe surfaces, in the construction of force measurers (calibration graphs are rich sources of representational learning), and exploration of buoyancy, students would engage in open discussion of what forces act and how best to represent them (including the customary school science protocols). The unit will end with a design task involving an egg drop in which students interpret their designs and results using force representations.

The emphasis in this sequence on negotiation of representations, open class discussion and exploration, and the focus on ideas in use, are part of what the Review is arguing for. Of course, this unit deals with traditional content. In another example from the Science in Schools research project we worked with Year 7 teachers to design a contextually based force unit.

Students were introduced to the broad thrust of the unit which was about forces and energy, and then spent a lesson at a local playground exploring the equipment. They generated questions, and then investigated them in a series of modelling activities back at the school. The aim of these investigations was to unpack the science underpinning the various bits of equipment, and the design issues at stake. The topic inevitably widened, for instance with a study of sound associated with a set of acoustic tubes.

**Inquiry, the nature of science, and community**

For some time 'working scientifically' has been an important part, in principle, of science courses in Australia. However, this is often too narrowly conceived and investigations should include both more open ended exploration of student questions, and inquiry into socio-scientific issues. The way evidence is used to develop and test science ideas is central to this, and schemes focusing on science argumentation have been developed (see for instance the Kings College IDEAS project http://www.kcl.ac.uk/schools/sspp/education/research/steg/ideas.html).

An influential UK curriculum – 21st Century Science – has as one of its core components a focus on the nature of science represented in contemporary society. It focuses on the way evidence is used in science in the public arena, highlighting ideas about science such as data and its limitations, the nature of explanation, risk, and how the scientific community works. It is a rigorous course that has impressed its initial critics.

A development that is increasingly attracting interest is the linking of school science with community and industry organisations to
create more authentic settings for science. Design competitions, environmental monitoring and regeneration projects, and biological survey work are examples of these. These projects represent the authentic end of what I am arguing should characterise the core focus for school science and we need to work out ways of bringing the core of such practices into the mainstream.

One project involves students having direct online access to research results from a leading microbiology laboratory and working with PhD students on interpretation. The DEST funded ASISTM project has spawned a number of such curriculum innovations, including one from SA where teachers and students are working with university researchers and PhD students, on data collection involving intensive measurement processes and data analysis. Other examples include students learning the chemistry of winemaking and winning awards with the resultant products, or a cluster of schools monitoring frog populations and engaging in a breeding program. Students give very good feedback in these projects, and teachers often say it has regenerated their own interest in science.

What are the implications?

What is being called for is already tested and accepted, in that there are schools and teachers and curriculum documents that support elements of it, even at the post compulsory level where disciplinary pressures are greatest. It is on the other hand challenging and revolutionary in its call to take the further step and shift the focus substantially towards these aspects of contemporary science teaching at the expense of the traditional commitments to declarative knowledge. This is a particular challenge given that these commitments are supported by an entrenched assessment system, and consistent with conservative public views about what it is to ‘know’ science. Nevertheless, all the indications are that the traditional system is failing us, and it is not hard to find practising scientists who advocate such change in the interest of bringing school science closer to the practice of science at the coalface, or professional science bodies now very concerned about the future of their disciplines.

Curriculum policy at the moment in Australia encompasses strangely contradictory elements. On the one hand many innovative government-funded projects such as ASISTM or SiS or Productive Pedagogies celebrate and encourage authentic settings and open pedagogies, yet there is a strong swing also to strong accountability frameworks, benchmarking and progression points that restrict innovation. While this ambiguity gives science teachers freedom to manoeuvre and to express a choice, in order to put in place the re-imagining that I am arguing for, we need a freshly conceived curriculum approach that is flexible, but unambiguous.

To put this in place, there are two major conditions that will need to be tackled. Firstly, such a re-imagining needs to be supported by a concerted (and probably national) effort to develop appropriate curriculum approaches and resources that deal with science in contemporary settings, emphasising analysis and interpretation of evidence. This needs to occur in partnership with teacher development and training initiatives. Teachers would need to be in the forefront of such developments. Deakin University has introduced a new combined science and science teaching degree that includes study of science in community settings, and the nature of science, and communication of science, alongside disciplinary subjects.

Secondly, we cannot, and should not, proceed down this path until we are satisfied we can pursue it with rigor, and this will require a major initiative developing different and more varied assessment practices. For too long, a misplaced sense of rigor has propped up the commitment to declarative knowledge structures as the core of science. The PISA (see http://www.pisa.oecd.org) assessment offers models that may be useful, and there are approaches to testing of practical skills developed by TIMSS (see http://nces.ed.gov/timss). The rich tasks notion developed in Queensland (see http://education.qld.gov.au/corporate/newbasics/html/about/about_rt.html) may also offer a way forward.

Whatever the case, the change will require courage and commitment, and will not be quickly achieved. However, for the sake of the nation’s future, it is a challenge that needs to be taken up.

References

