Exploring the Australian Science Curriculum: A way forward?

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Abstract

There is considerable international concern about science education based on the number of students engaged with science and mathematics, and research showing student disenchantment with school science curricula. In this presentation I will trace through a history of concerns with school science, and describe the recommendations and curriculum responses to these concerns internationally and particularly in Australia. The new Australian Science Curriculum is based around ideas related to scientific literacy and inquiry curriculum, and includes science inquiry skills and 'science as a human endeavour' as major strands. I will describe the features of the course and raise the question – does it represent a productive way forward? The various aspects of the course are related to current directions in science education research, and examples will be given of my own involvement in national curriculum initiatives, into school-community links, and Deakin research into a pedagogy that focuses on student generation of representations, as examples of ways forward for improving student engagement with learning science.

International concern for science education

There has been increasing international concern for the supply of science and technology professionals needed to maintain a country's viability as a technologically advanced competitive economy, and this concern has been articulated in a series of major government reports from Europe, the UK, the U.S. and Australia (European Commission 2004; DEST 2003; Goodrum, Hackling, & Rennie 2001; National Academies Committee (COSEPUP) 2006), all of which call for concerted action. There have been concerns about the increasingly negative response to science across the early secondary school years. There have been some indications that this decline in fact begins in the upper primary school or even earlier.

In 2007/8 a review was commissioned by the Australian Government to explore the factors across the primary-secondary school transition that affected the flow of students through the 'STEM pipeline' on to employment in science related professions. The review (Tytler, Osborne, Williams et al. 2008) identified, using key search terms, more than 1000 articles potentially relevant to this question and constructed a list of more than 500 studies of particular relevance.

Three factors stand out as major determinants of student interest in and engagement with school science – what students bring to science from their early experiences, gender, and the quality of teaching.
**Student attitudes to and engagement with science**

What are the reasons for students’ increasingly negative attitudes to science across the secondary school years? A negative attitude towards the relevance of science content for their lives was a strong theme in the Australian report on the status and quality of teaching and learning of science (Goodrum, Hackling, & Rennie 2001, Goodrum 2006, Rennie 2006). A number of studies have explicitly linked the decline in student interest with the nature of the traditional science curriculum and its inability to make science meaningful and interesting to students (Aikenhead 2005; Fensham 2006; European Commission 2004).

For greater insight into the reasons for these negative attitudes to science we must look to closer studies of student perceptions of the nature of school science and the factors determining their engagement with it as an interesting subject or a potential career. Over the last decade there have been three separate studies conducted, in different countries, which have sought to locate answers to the questions of what is really turning our students off science, and what can be done about it. The three studies were from Australia (Lyons 2005), Sweden (Lindahl 2007) and the UK (Osborne & Collins 2001). They were similar in that they were substantially interview-based and dealt with students in the years in which they were making choices about their future studies.

Lyons’s (2005) meta-analysis of the findings of these studies highlighted three major themes:

- the transmissive pedagogy that characterised school science
- the decontextualised content that did not engage students’ interest or commitment
- the unnecessary difficulty of school science.

Lindahl’s (2007) study, which was described above, found that students resented the lack of opportunity for personal opinion and expression in science, caused by the narrow range of transmissive pedagogies used. They were also not attracted to what she called the semiotics of the classroom: the smell of the laboratory, texts crammed with facts and teachers who did not laugh. In her study there were a number of academically strong students with an interest in science as presented in popular media, who rejected school science as something very different.

Lyons (2005) characterised the transmissive pedagogy of science as a feature reported so widely that it seemed to be regarded as an inherent characteristic. Osborne’s and Collins’ (2001) informants talked of ‘right or wrong answers’ with no room for creativity or time, in the rush to ingest concepts, to discuss or reflect or offer opinions. They argue that this aspect of school science is a response to an overfull curriculum in which students are ‘frog-marched across the scientific landscape, from one feature to another, with no time to stand and stare, and absorb what it was that they had just learned’ (p. 450). They also found a perception of the irrelevance of school science to be ‘a recurring theme’ among students regardless of whether they intended to continue with science study (p. 449). They concluded that teachers too infrequently attempted to link science concepts to everyday life.
Student identity in late modern societies

Schreiner and Sjoberg (2006) link the declining interest in school science, shown by markedly less interest in science in the developed countries compared to less developed countries, to identity characteristics of youth in late modern societies. They speculate that the main reason that young people, especially girls, are reluctant to participate in the physical sciences is because they often perceive the identities of engineers and physicists as incongruent with their own. There is an abundant literature (Boaler 1997; Lightbody and Durnell 1996a; Mendick 2006; Walkerdine 1990) which argues that STEM subjects and careers have a masculine image that leads girls to reject identities connected with STEM. Schreiner and Sjoberg suggest that, if this perspective is correct, then attracting more students into STEM pathways will require transforming the images of STEM work to address the ideals of contemporary youth, and updating the content and practice of school STEM subjects to make these values more apparent. They identify these ideals as connected with late modern values such as self realisation, creativity and innovation, working with people and helping others, and making money.

The STEM review (Tytler, Osborne et al. 2008) identified a strong connection between interest, identity, and self-efficacy in framing students' response to science. A key aspect of the identity construct relates to students' perception of the nature of involvement in STEM as a possible future and the need to represent in primary school science the people who work in science and the nature of their passion for that work. Elsewhere I have argued (Tytler 2007) that traditional school science fails to adequately represent the nature of contemporary science practice and its personal and social relevance, and ways need to be found to either arrange for the school curriculum to better represent this practice, or to find ways of directly exposing students to the work of science professionals. These relationships are represented in Figure 1.

Current trends in science education pedagogy and curriculum

Scientific literacy – science for the future citizen

The argument for a broadening of the science curriculum to better meet the needs of all students underpins the call for a scientific literacy focus (Bybee 1997; Goodrum, Hackling, & Rennie 2001). Scientific literacy has been defined in different ways, but a commonly quoted definition is that developed by the OECD. The PISA assessment project describes it in terms of an individual's:

• scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues

• understanding of the characteristic features of science as a form of human knowledge and enquiry

• awareness of how science and technology shape our material, intellectual, and cultural environments
• willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen.

Figure 1: Identity, self-efficacy, interest and the nature of science
Rennie (2006, p. 6), in her unpacking of the characteristics of a scientifically literate person, emphasises an action-oriented version of the scientifically literate person (see Figure 2).

Figure 2: Leonie Rennie’s definition of scientific literacy

**Scientific Literacy – a definition**

- Are interested in and understand the world around them
- Engage in communication of and about science
- Make informed decisions about the environment and their own health and well-being
- Are able to identify questions, investigate and draw evidence-based conclusions
- Are sceptical and questioning of claims made by others about scientific matters

**Inquiry curricula**

The close relationship between the processes, and conceptual ideas of science, is exemplified by ‘inquiry’ curricula in science. Inquiry has a long history in the ideas of educators like Dewey (1916), Bruner (1960) and Schwab. Schwab (1962, 1965) famously described the traditional science curriculum as a ‘rhetoric of conclusions’ and argued for a science curriculum that educates students in what he called the *syntactical* as opposed to the *substantive* structure of the discipline: the way science ideas are posed, experiments are performed, and how data is converted into scientific knowledge. Inquiry teaching has been a strong theme in the USA, and has counterparts in investigative and process emphases in curricula elsewhere, including in Europe.

One of the difficulties of talking about inquiry curricula is that the term covers a multitude of methods, from illustrative, set-piece experiments, to investigations with strong guidance from instructions or the teacher, through to more open-ended investigations in which students pose and explore their own questions. In many documents for primary schools, the term seems to be used interchangeably with ‘hands on’ science, as in ‘hands on pedagogy’ in many learning areas. There is thus a need to clarify the terminology. Osborne (2006) makes the point that:
Four decades after Schwab's (1962) argument that science should be taught as an 'enquiry into enquiry', and almost a century since John Dewey (1916) advocated that classroom learning be a student-centred process of enquiry, we still find ourselves struggling to achieve such practices in the science classroom. (Osborne 2006, p. 2)

Denis Goodrum (2006) refers to the lack of uptake of inquiry in Australian classrooms, despite the consistent rhetoric of curriculum documents. Osborne argues for an inquiry perspective in school science on the basis of the need for citizens to be part of the decision-making processes around 'the developments of science and technology which are most likely to pose the political and moral dilemmas for the generations to come' (p. 3). As described earlier, Osborne argues for a need to focus on how evidence is used to construct explanations and what criteria are used in science to evaluate evidence. With this in mind, he and colleagues (Simon, Erduran, & Osborne 2006) have worked with teachers to develop a model for introducing argumentation activities into science classrooms, aimed at modelling the way knowledge is warranted in science. The UK work on argumentation has produced curriculum materials: Ideas, Evidence and Argument in Science Education (IDEAS: http://www.kcl.ac.uk/schools/sspp/education/research/steg/ideas.html) which are being widely used. These involve activities that challenge students, and encourage them to hypothesise and resolve claims and counterclaims on the basis of evidence.

**The role of representation in learning science**

A recent Australian Research Council project The role of representations in learning science (RiLS) has taken this literacy perspective in what are proving to be very productive directions. RiLS is generating pedagogical principles that instantiate a. socio cultural perspectives that learning science involves indiction into the discursive practices of science, b. insights from recent work in cognitive science which acknowledge the role of perception and informal reasoning processes in learning and the role of language and representation in framing our thinking and learning, and c. inquiry principles of learning science.

**Figure 4: RiLS pedagogical principles**

1. Planning needs to be based on a clear conceptual focus to guide refinement of representational work.

2. Representational generation and negotiation need to be the focus of teaching and learning, involving:
   - students being active and exploratory in generating, manipulating and refining representations
   - a strong focus on representational challenges
   - a rich perceptual/experiential context to activities
   - the generation and coordination of multi-modal representations
• interplay between teacher-introduced and student-constructed representations
• explicit discussion of representations
• acknowledgement of the partial nature of any representation
• ongoing assessment of adequacy of representations

3. Activity sequences need to focus on engaging students in learning that is personally meaningful and challenging.

4. Formative and summative assessment needs to involve students in generating and interpreting representations.

In working with both primary and secondary teachers over a range of science topics, analysing video records of classroom practice, student work, teacher insights and student learning outcomes, the RiLS team has developed a set of principles that essentially operationalise the SIS components dealing with explorations of ideas and evidence, higher level thinking, and assessment.

The RiLS Pedagogical Principles are shown in Figure 4. Essentially these involve an explicit focus on students generating and negotiating representations in exploring and explaining science phenomena. The teacher’s role is to set challenges that involve students generating representations of science ideas, to introduce as needed the canonical representations of science (such as representations of the particle model of matter, or ways we might represent energy, or food chains), and to support students in coordinating and refining their representations. The approach draws on a growing literature advocating active generation of representations by students and the links between representations or models and reasoning and learning (Carolyn, Prain & Waldrrip 2008; Cox 1999; d’iSessa 2004; Ford & Forman 2006; Greeno & Hall 1997; Hubber, Tytler & Haslam 2010; Lehrer & Schauble 2006a, b; Prain, Tytler & Peterson 2008; Tytler & Prain 2010).

In a Grade 5/6 (age 10/11) unit on animal adaptation for instance, teachers taught students how to use a quadrat for sampling and discussed with children how they might collect data and represent the animals found in a habitat and the habitat conditions themselves. Figures 3 and 4 are excerpts from a student notebook and a group poster, showing representations of animal population within a habitat (diversity concept), and animal movement (structure and function concept). Analysis of student work on a three dimensional model to explore animal movement (Tytler, Haslam, Prain, & Hubber 2009) showed how different stages of drawing, talk, 3D model construction, and gesture were combined by two students to reason and communicate about how a centipede moves its legs and its body in an undulating pattern. Figure 5 is a post test response for a Grade 5/6 unit focusing on molecular representations of evaporation. The project has demonstrating the close link between representations, reasoning and learning in science. Results from the project show clear evidence of significant student learning, of teacher enthusiasm describing student engagement in quality learning, and of shifts in teacher classroom practice and in their perceptions of what it is to learn science. The research team worked closely with the teachers in planning these units, and it remains to be explored how this approach might be effectively disseminated at a system level.
Figure 3: Student graphical representation from notebook

Figure 4: Representation of animal movement from group poster
Figure 5: An evaporation unit post test response to the question ‘where do the droplets of water I clouds come from?’

3a. “Clouds are made of tiny droplets of water”, said Mrs Pike. Then she added: 
"Where do you think the water in the tiny droplets of water in the clouds comes from?" 
Use representations to answer Mrs Pike’s question.

3b. Mr. King added: I have a challenge for you. Use representations to show how little drops of water form clouds.

The molecules in the diagram above are gas and liquid.
In the first picture the molecules are evaporated and are moving. In the 2nd one they are high in the sky and forming clouds together.

humanistic science education

Aikenhead (2005) argues that there is abundant evidence that traditional school science is not meeting the needs of students, and that curricula with the characteristics he identifies with humanistic science are of more interest. Aikenhead labels traditional science education as a ‘pipeline’ version of the science curriculum aimed at providing technical disciplinary training for future science professionals, as opposed to a humanistic version that would present science more broadly as a human endeavour. The contrast between these versions of science education is shown in Table 1.
Table 1: Aikenhead’s contrast between a ‘humanistic’ and a traditional ‘pipeline’ version of science education.

<table>
<thead>
<tr>
<th>Humanistic science education</th>
<th>Traditional science education</th>
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<tbody>
<tr>
<td>Citizen preparation for everyday world</td>
<td>Pre-professional training for scientific world</td>
</tr>
<tr>
<td>Attention to several sciences (established, citizen, frontier, etc.)</td>
<td>Emphasis on established science</td>
</tr>
<tr>
<td>Scientific and moral reasoning with values</td>
<td>Solely scientific reasoning</td>
</tr>
<tr>
<td>Knowledge about scientists and science</td>
<td>Knowledge of canonical science</td>
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Aikenhead’s vision of a humanistic science education aligns with Roberts’ (2007) Vision II science literacy agenda, emphasising learning about the operation of science in the world including the human practices of science and its social applications and implications as central to the purposes of school science. The humanistic science education column contains emphases that are consistent with the findings of the STEM review of Tytler, Osborne et al. (2008) concerning factors affecting students’ aspirations towards science. This notion of a humanistic science education is echoed in a number of science curricula including Sweden’s ‘use of knowledge’ and Australia’s ‘science as a human endeavour’ organiser which is about:

the way science influences society through its way of thinking and world view as well as the way societal challenges or social priorities influence the development of scientific research. It highlights the need for informed, evidence-based decision making about current and future applications of science that impact on society and the environment and on other social and ethical issues. It acknowledges that science has advanced through, and is open to, the contributions of many different people from different cultures at different times in history and offers rewarding career paths. It acknowledges that in decisions about science and its practices, moral, ethical and social implications must be taken into account. It is intended that students will use their scientific understanding to engage in a future-oriented way with relevant local or global issues in addition to sustainability. (MCEECDYA 2006, p. 8: http://www.mceecdya.edu.au/mceecdyainstatements_of_learning,22835.html)

Thus this organiser, which sits alongside ‘science as a way of knowing’ and ‘science as a body of knowledge’, picks up on social, personal and ethical aspects of science and also contemporary socio-scientific issues, and human aspects of science work including careers.
School-community links in teaching science

It has been argued, arising from the research on student identity, and also on interest and relevance, that the primary school science curriculum needs to link students to contemporary uses of science and to represent the work and experience of science professionals more directly. There is an increasing incidence of community projects that do this, in Australia and elsewhere. These are driven by a concern to make schooling more relevant to students and continuous with their lives. The SIS Components include this principle:

The classroom is linked with the broader community. A variety of links are made between the classroom program and the local and broader community. These links emphasise the broad relevance and social and cultural implications of science, and frame the learning of science within a wider setting. (Deakin University 2003, p. 9, 40)

Many of the interviewees in the SIS research project employed community links in their programs. Examples included a secondary science coordinator in a school in a coastal area who drew on local resources to run units on dune ecology, waves and the physics related to surfing. Some primary schools explicitly nourished a range of community links as part of the setting of the science curriculum:

Much of the school's integrated program is science based. The program includes major emphases on community links including science competitions, local environmental projects, and links with outside bodies, professional development initiatives, and assessment and reporting initiatives. Rachel (the teacher) has worked hard to develop a culture of parent involvement in the school, and sees this as a way to drive the science initiative. (Tytler, Waldrip, & Griffiths 2004, p. 183–4)

The SIS component was reconfigured in later more generic versions to emphasise more strongly the link between meaningful learning and professional and community practice: ‘Learning connects strongly with communities and practice beyond the classroom’ (Victorian DE&T 2004).

Rennie (2006) described school–community projects that were very successful in engaging student and community interest. One was a Year 9 air quality project that identified the major cause of air pollution in a mill town. The students began the project suspecting the local mill but soon established the cause to be domestic wood-fired stoves and heaters. They began a campaign for a buy-back scheme, and received an enormous amount of support and attention from the community. The case is a good example of a socio-scientific issue involving data collection (there were difficulties in negotiating a continuous on-line stream of meteorological data), argumentation, the intersection of science with social dimensions of an issue, and social action. As such, it offers a more authentic experience of a contemporary science issue than the more structured socio-scientific packages described above.

Rennie argues positive outcomes from these community projects, and identifies a set of guiding principles for the success of school–community projects, including that: they need to be based on issues coming from the community; they require local knowledge; they are
integrated into science at the school; they involve negotiation and decision making with the community; and they have a tangible outcome.

In a study of 16 ‘innovation exemplars’ from more than 200 science, technology and mathematics projects funded as part of the Australian School Innovation in Science Technology and Mathematics (ASiSTM: http://www.asistm.edu.au/asistm/) project, Tytler, Symington & Smith (2009) argued that the pedagogical practices spawned in these projects, for which partnerships with community or industry or university organisations was a requirement, are more varied and student centred than is traditionally the case in science classrooms. These approaches include:

- Project based or problem based learning;
- A strong skills focus involving scientific and related processes;
- More open pedagogies where students are given increased agency;
- The creation of knowledge by students rather than simply knowledge absorption;
- A wider set of knowledges including knowledge of processes, interdisciplinary links, knowledge about the contemporary and local use of STM, and knowledge of people using STM in employment;
- A ‘real’ audience for students’ work;
- Field trips and projects in the local environment;
- Working with scientists and with local community members; and
- Involvement of parents and the wider school community.

The study found that these projects increased student engagement with science, and also involved significant teacher professional learning.

Re-imagining the science curriculum

In 2006 the Australian Council for Education Research (ACER) ran an international conference specifically focusing on the problems of engaging students in science, entitled ‘Boosting science learning - what will it take?’ (http://www.acer.edu.au/research_conferences/2006.html). This conference led to a commissioned monograph (Tytler 2007) which drew on the conference inputs and on the literature more generally, to outline a way forward for school science. That document, which has been quite influential in Australian science education, drew on a strong feeling for change expressed at the conference plenary session to argue for a ‘re-imagining’ of science education.

In the re-imagining science monograph (Tytler 2007) I identified four interlinked concerns that frame the current malaise in science education, that have galvanised government action in many countries: falling numbers of science students at all levels beyond the compulsory years; a current and looming shortage of teachers of science; 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 we think it should be, compared to other subjects.
In the review I argued that the cause of these problems in science education can be linked to a number of fundamental changes that school science has failed to respond to. These include:

- Changes related to the nature of post-industrial societies. Results from the international ROSE (Relevance of Science Education) project (Sjoberg & Schreiner 2005) 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.

- Changes in the accessibility of science knowledge and in science itself—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 (Aikenhead 2005; Ziman 2000).

- Changes in the nature and expectation of youth— young people coming through secondary education are very different now to the faithful consumers presumed by traditional school science. They respond to the complexity and uncertain future characterising life in contemporary technological societies, by demanding flexibility and skill development in their education.

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. From the review, a re-imagined science education was outlined as a vision for the future, and this is represented in Table 2. In a foreword to the review, the noted plant biologist and then Australian Chief Scientist, Dr. Jim Peacock, made the following points:

The way in which I learned science at school does not meet the needs of today's students. In my lifetime, scientific research has broadened from an individual-oriented approach to team-based work and collaboration with other researchers and industry. Collaborative science is essential if we are to address national impact and global problems such as climate change. A different skills set is needed in today's scientists. ...

Science is a constantly evolving field. Thus, much of the content knowledge I learned in school and university was not directly used in my career as a plant scientist. I learned to approach individual experts in a field, tracking information in how to tackle an unknown.

Every day we are faced with unfamiliar tasks and required to make decisions in unfamiliar contexts. Students will become more effective citizens by being able to locate, analyse and critique information to form their own opinions rather than being able to provide the atomic number of an element such as lead.

**Table 2: Strands for a re-imagined science curriculum (based on Tytler 2007)**

<table>
<thead>
<tr>
<th>Conceptual content and context</th>
<th>The curriculum needs to seriously cater for student interest and be set within contexts that will be meaningful to all students. The amount of content coverage needs to be reduced. Content should be chosen to represent contemporary</th>
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practice, and with a view to its usefulness in students' current and future lives as citizens. It should acknowledge value positions, and include sustainability as a major focus. Content specification needs to allow room for initiatives built around local conditions.

<table>
<thead>
<tr>
<th>The way science works</th>
<th>The curriculum should strongly represent the nature of contemporary science and the way science ideas are developed and tested against evidence. Students should access historical and contemporary narratives of science inquiry including the work and the beliefs of science professionals.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigative science:</td>
<td>For some time 'working scientifically' has been an important part, in principle, of most science curricula. However, this is often too narrowly conceived and investigative design should encompass a range of methods and principles of evidence including sampling, modelling, field-based methods, data handling using a variety of representations such as graphs, tables, drawings and mathematical formulations, and the use of evidence in socio-scientific issues. Investigations should frequently flow from students' own questions. The way evidence is used to develop and test science ideas is central to this.</td>
</tr>
<tr>
<td>Capabilities relating to science</td>
<td>The curriculum needs to explicitly aim to widen the purposes and student capabilities currently associated with school science to include understandings of the nature of science, the capacity to investigate and reason, dispositional capabilities such as interest and curiosity, and more generic capabilities such as thinking analytically, communicating and working in teams, and creativity and imagination. More work needs to be done on how they can be developed and assessed in science.</td>
</tr>
<tr>
<td>The setting of school science:</td>
<td>A development that is increasingly attracting interest is the linking of school science with community and industry organizations to create more authentic settings for science and represent contemporary science practices and concerns (Rennie 2006; Tytler et al. 2008). Design competitions, environmental monitoring and regeneration projects, and biological survey work are examples of these. Research has shown the potential of such initiatives to engage both teachers and students in significant learning. Ways need to be found to embed school–community initiatives into the curriculum in sustainable ways.</td>
</tr>
<tr>
<td>Assessment</td>
<td>Assessment approaches need to be developed that support a wider range of curriculum emphases. This includes assessment of investigative capabilities, the capacity to explore science in social and ethical contexts, reasoning and imagination, and understandings of the nature of science. Ways need to be found to embed authentic, learning-based assessment in mainstream practice, alongside more imaginatively conceived test-based items.</td>
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The Australian Science Curriculum

The Australian Science Curriculum currently (ACARA 2010) being developed has its roots in a set of goals for schooling that were articulated in a document known as the 'Melbourne Declaration'. Excerpts from this document, Figure 6, show the important role of values, and citizen empowerment, that underpin curriculum thinking in Australia.
Figure 6: The Melbourne declaration (MCEETYA)

Our educational goals for young Australians

Successful learners...

- have the essential skills in literacy and numeracy ...
- are creative and resourceful and are able to think critically.
- are able to learn and plan activities independently, collaborate ...

Confident individuals...

- have a sense of optimism, self-esteem ...
- have a sense of respect for others, control over their lives ...
- are creative and productive users of technologies ...

Active and informed citizens...

- have the capacity and inclination to act with moral and ethical integrity
- are able to relate and communicate across cultures, especially in relation to cultures and countries of the Asia-Pacific ...

The Australian science curriculum is built upon a framing paper developed by Denis Goodrum, which outlined three content strands that pick up many of the major trends in curriculum thinking outlined in the research overview above. The document drew heavily on thinking in the Goodrum, Hackling and Rennie (2001) report and subsequent work by Goodrum and Rennie, and also the Re-imagining monograph of Tytler (2007). The three strands are:

1. Science understanding: This is evident when a person selects and integrates appropriate science knowledge in ways that explain and predict phenomena, and applies that knowledge to new situations and events. Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established by scientists over time.

2. Science inquiry skills: These involve posing questions, planning, conducting and critiquing investigations, collecting, analysing and interpreting evidence and communicating findings. This strand is concerned with evaluating claims, investigating and making valid conclusions.

3. Science as a human endeavour: Science influences society through the posing and responding to social and ethical issues and science research is influenced by societal challenges or social priorities

The framing paper also recognized three key terms that would underpin curriculum planning:

1. Contemporary science involves new and emerging science research and issues of current relevance such as energy resources and technology, climate change and adaptation, biodiversity and ecological sustainability, materials science and engineering, health and prevention and treatment of disease.
2. Technology (and design) ... can be used to solve problems about human needs. Science knowledge has often led to applications in society in the form of technologies ... In turn, developments in technology have made possible new ways for scientists to explore.

3. Unifying ideas include: patterns, systems, questioning and speculating; cause and effect; evidence, models, explanation and theories; change, equilibrium and interdependence; sustainability of systems; form and function.

In planning for the development of student capacity across the stages of schooling, descriptors of outcomes for each content strand are given at the different year level bands. Table 3 gives examples of these outcome descriptors for years 7-10, to illustrate the nature of the content strands.

Table 3: Selected outcomes for Years 7-10

<table>
<thead>
<tr>
<th>Science understanding</th>
<th>Physics and chemistry</th>
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<tbody>
<tr>
<td></td>
<td>nature of matter, including particle theory</td>
</tr>
<tr>
<td></td>
<td>forms of energy, energy transfer and storage ...</td>
</tr>
<tr>
<td></td>
<td>Biology ...</td>
</tr>
<tr>
<td></td>
<td>Earth science ...</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Science inquiry skills</th>
<th>Formulate scientific questions or hypotheses for testing</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Design and conduct science investigations involving measurement and repeated trials</td>
</tr>
<tr>
<td></td>
<td>Gather and organise data from a variety of sources</td>
</tr>
<tr>
<td></td>
<td>Analyse and test models and theories based on the evidence available</td>
</tr>
<tr>
<td></td>
<td>Explain and summarise patterns in data using science concepts</td>
</tr>
</tbody>
</table>

| Science as a human endeavour | Be aware of contemporary issues such as water and its management, climate change, stem cell research, nanotechnology, gene technology |
|                             | Apply scientific understandings to make responsible, ethical and informed decisions about issues |
|                             | Be aware of the nature of science and research of Australian scientists |
|                             | Appreciate that science provides rewarding careers |
|                             | Appreciate the diversity of people who have contributed to, and shaped the development of, science |

The framing paper underwent a process of consultation and review and was accepted in early 2009 as the basis of curriculum writing. Since then, teams of writers have been developing more detailed curriculum achievement standards and exemplary content which were put out for consultation in early 2010 and are currently being re shaped. Examples of these are shown in Table 4.
Table 4: Examples of the Science Curriculum Year 8

<table>
<thead>
<tr>
<th>Strand</th>
<th>Content description</th>
<th>Content elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Inquiry Skills</td>
<td>Construct and use tables and graphs to represent and analyse data, including using ICT</td>
<td>• designing appropriate tables, including the use of correct units, to record data&lt;br&gt;• representing their data using graphical methods and applying conventions used in plotting graphs&lt;br&gt;• using spreadsheets to aid in the presentation and simple analysis of quantitative data&lt;br&gt;• understanding different types of graphical representation and considering the advantages and disadvantages of the various types</td>
</tr>
<tr>
<td>Science as a human endeavour</td>
<td>Science helps individuals and communities to make choices about issues in life and evaluate claims made in a range of media and advertising</td>
<td>• evaluating, through a field or case study, how humans impact on balance in ecosystems in positive and negative ways (eg adding or removing endemic or feral organisms, sustainable use or over-harvesting of resources, and restoration or pollution of habitats)&lt;br&gt;• comparing the effectiveness of different products (eg sunscreens, detergents, insulators) and using understanding about chemical and physical properties to evaluate claims&lt;br&gt;• comparing the uses of solid, liquid and gaseous fuels, including safety and the reasons for choice of use in different situations (eg comparing coal, oil and gas domestic heaters)</td>
</tr>
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</table>

One of the key issues in writing curriculum is the way that the vision of the curriculum designers is translated into a coherent content package that reflects the original intention. This in part is determined by the quality of the writers and the process through which this is done, but is in part determined by the politics of who has influence on the content specification and what are the processes of balancing arguments for inclusion and exclusion of particular areas.
There has been a lot of criticism of the current version of the content document. The Deans of Science have supported strongly the vision put forward in the framing paper but decried the lack of coherence of the content document and its failure to integrate the three strands in a meaningful way. High level critique in Victoria has argued for a reduction in content amount, and for the possibility of supporting locally produced curricula reflecting particular contexts of schools, a strong tradition in that state.

**Curriculum initiatives**

Alongside curriculum reform, approaches to improvement of science teaching and learning involve the production of resources, and the professional development of teachers. There is abundant evidence that significant teacher change is best supported by longer term initiatives based in the culture of the school with room for local ownership, rather than short workshops. A major Australian project, School Innovation in Science (SIS: Tytler 2009), focused on teacher and school development based on a set of pedagogical principles, and was very successful in supporting teacher improvement. Other recent projects at the national level (Primary Connections (http://www.science.org.au/primaryconnections/) and Science by Doing (http://www.science.org.au/sciencebydoing/index.htm), both initiatives of the Australian Academy of Science, and the STELR project of the Australian Academy of Technological Sciences and Engineering (http://www.stelr.org.au/)) have used a combination of resource development and structured professional learning involving distributed leadership of communities of inquiry.

**Concluding comment**

There is broad agreement internationally concerning the directions science education needs to go in, to engage school students in significant scientific reasoning and learning. There is much interesting work being done in schools and by researchers in developing pedagogical, content and assessment approaches to support these directions, and these are represented in the Australian science curriculum framing paper. However, the translation into detailed content specifications has thus far eluded wide agreement amongst key stakeholders and it remains to be seen what the next stage in this national innovation will be.

**References**


Sjøberg, S., & Schreiner, C. (2005). How do learners in different cultures relate to science and technology? Results and perspectives from the project ROSE. Asia Pacific Forum on Science Learning and Teaching, 6(2), 1-16.


