
References

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The Australian Science Curriculum

ARTICLE: ONE

The Australian Science Curriculum has appeared at a time when there is widespread concern for the quality of science teaching and learning in Australia and the engagement of students in learning science, leading to calls for significant reform. The new curriculum thus carries the hopes of reform-minded scientists and educators for a change in the way science in schools can support teaching practices that engage students in quality learning. This analysis will examine whether it is an adequate vehicle for doing this. Will it live up to our expectations?

The context

In 2001 a major government commissioned report on the State of Science in Australian schools (Goodrum, Hackling & Rennie, 2001) found that the reality in Australian science classrooms was that students were predominantly positioned as passive learners, they did not feel engaged with science ideas, were increasingly negative about science across their schooling, and did not see the relevance of science to their lives. Teachers were not enthusiastic about teaching science. This was despite decades of research that emphasised the need to move science teaching away from a predominantly teacher-centred, transmissive style in which students were taught by 'telling', and to move the curriculum towards an 'inquiry' approach that placed greater emphasis on student questioning and investigating. Further to this, in primary schools very little science was being taught -- far less than the recommended level.

Goodrum et al. (2001) advocated 'science literacy' as the appropriate basis for framing the school science curriculum, moving away from a traditional view that sees school science as a training ground for future scientists, to one that emphasises the preparation of students to engage with science as future citizens. This notion encompasses not only a familiarity of core science concepts but also the capacity to engage with and be critical consumers of science in the media and in public policy, to make decisions that involve science in their personal lives, as well as being schooled in the nature of science; the way it builds knowledge and the way science interacts with technology and society.

A major national conference organised by CSIRO in 2006 (http://www.acer.edu.au/research_conferences/2006.html) brought together a range of national and international speakers to discuss the 'crisis' in school science -- negative student attitudes, shallow learning, and diminishing retention into post compulsory science -- and what can be done about it. Many speakers advocated a need to change classroom practices in science in order to have science made more meaningful for students and to engage them in quality learning. Notions that were regularly drawn upon were those of:

inquiry, involving the need to have students engage more meaningfully with the practices by which science builds knowledge
context, involving a need for students to see the science they are studying as relevant to their lives and interests
science literacy, involving developing a range of student capabilities to engage with science ideas in a range of contexts. Rennie (2006,p. 6), describes the characteristics of a scientifically literate person thus:
* is interested in and understands the world around them

* engages in the discourses of and about science

* is able to identify questions, investigate and draw evidence-based conclusions

* is sceptical and questioning of claims made by others about scientific matters

* makes informed decisions about the environment and their own health and well-being.

Arising from this conference, a monograph was produced (Tytler 2007) which called for a 're-imagining' of science education. This publication has been influential in policy directions and, along with the Goodrum et al. (2001) report, was acknowledged as influential in the framing paper for the Australian Science curriculum (Goodrum 2008). The framing paper to a large extent takes its lead from these concerns and ideas. However, the process of writing the framing paper, and particularly the process of translating it into a curriculum document, involved consultation at many levels, across all states, representing a range of interests. The process also inevitably reflected the views and experience of the writers and their capacity to pull together these multiple strands into a coherent framework. In reviewing this new Australian curriculum, the questions for us then become:

Does the Australian Science Curriculum adequately reflect the ideas found in the science education literature concerning how best to address contemporary concerns about school science?
Is it a document that might provide some positive directions for improvement in science teaching and learning?
Are there particular features of science teaching and learning that are privileged, or marginalised?
What further resources and support are needed in order to maximise the opportunity this curriculum offers, to improve the engagement with quality science learning for Australian students?
Ultimately, the key issue is whether this curriculum might form the basis of change in a productive direction for teachers of science in Australia, and their students.

The structure of the curriculum

The curriculum is framed around three interrelated strands: Science Understanding, Science as a Human Endeavour, and Science Inquiry Skills. These strands are equivalent to the three organisers developed in the 2006 Australian Statements of Learning (http://www.mceetya.edu.au/verve/_resources/Science_SOL06.pdf), which have been represented also in some state curriculum updates (Victoria and Tasmania for instance). The strands were strongly supported in the Framing Paper consultation. Two of the strands, understanding and inquiry skills, represent a way of organising science curricula that has underpinned outcomes based curricula in Australia for two decades, and relate to the previous attempt to introduce national consistency in curricula.

The breakdown of Science Understanding into Physical, Chemical, Biological and Earth and Space Sciences is consistent with current curriculum writing, although the naming has moved to traditional terminology where previously 'Natural and Processed Materials' or 'Life and Living' fore-grounded phenomena-in-the-world and de-emphasised the disciplinary, structural nature of the knowledge. This shift towards disciplinary traditions is characteristic of the thrust of the document overall, as we discuss on the following pages.

Science Understanding strand

The sequencing of content through the year levels is broadly reasonable but in many cases strangely arbitrary and trivial. For instance, in Year 5 there is a content description that describes a fundamental principle; 'Living things have structural features and adaptations that help them to survive in their environment', sitting alongside a content description, "The Earth is part of a system of planets orbiting around a star (the sun)" that seems to imply no level of understanding beyond description.

The fact that the content descriptions are often of topics rather than implying a 'standard' has shifted the balance from an outcomes specification towards a focus on 'inputs'. There is now a tighter prescription of topics (e.g. light and sound at Year 1, force and motion Year 2, heat at Year 3) compared to current frameworks documents in a number of states, in which the outcomes have been designed to represent conceptual growth along a more generally conceived dimension that attempted to transcend topics and focus on understanding of key principles underpinning specific contexts (such as 'light', or 'animals'). Further, rather than having standards at two year intervals, which has been the common practice, for this understanding strand these are now yearly. The result of this will be to require systems and teachers to look carefully at their current practices and make adjustments.

One example of the implications of this specificity was felt in aligning the national STELR project, which included significant sequences in energy and renewable energy, and electricity, at Year 10 level. Energy and electricity are now in separate years, which has caused some difficulty in providing a coherent unit around the topic of climate change and alternative energy provision. This topic specificity on the outcomes at single year levels will make it harder for schools to successfully initiate inter-disciplinary units of work.

Science Inquiry Skills strand

The Science Inquiry Skills strand broadly parallels the 'working scientifically', 'skills', 'inquiry', 'science at work', or 'ways of working' strands of current state curricula. The breakdown of the inquiry skills strand is broadly consistent with what is in these strands. In many cases these strands contain themes to do with science-society interactions and human involvement with science, prefiguring the 'human endeavour' strand of the Australian Curriculum. In the case of Tasmania, science communication has been a separate strand. Overall, however, the Science Inquiry Skills strand covers familiar territory, and the break up into sub-strands is understandable and useful, identifying the major phases of scientific knowledge-building processes including evaluating, and communicating science. What is welcome in the curriculum is the prominence given to inquiry processes through the strand. The year level descriptions are explicit and for the most part appropriately pitched. A problem we found with earlier drafts that limited young children to observation and description has been at least in part resolved so that young children in this curriculum are asking questions, exploring representations of scientific information, and engaging in discussion of patterns and relationships. It is not until Year 5/6 however that students are presumed to use evidence to develop explanations. There has been some quite trenchant criticism of the use of Piagetian stage ideas to frame science curricula that underestimate children's capacity to engage with ideas and interpret evidence. Kathy Metz (1995,1997) argued, on the basis of the psychology literature and her own work with K-2 children conducting investigations, that the presumption that children of this age should be restricted to observation, classification and pattern seeking fell well short of their actual capacity for reasoning. Our own research has supported this (Tytler & Peterson, 2003; 2004) showing that many Prep children are capable of proposing and judging science explanations and that this is quite common by Year 1.

There is clear evidence in the literature that inquiry approaches, which have students questioning and exploring and making decisions, engage them in quality learning and support the development of higher order thinking. There is also ample evidence that in Australia and internationally, inquiry approaches and investigative work have existed as the exception rather than the rule as classroom practices. We have also found (Symington & Tytler, 2011), in a recent exploration of schools involved in the BHP Billiton award scheme, that in states that have recently and explicitly embedded investigative work into the curriculum, teachers and schools are encouraged to adopt the pedagogies needed to support this. Hopefully, the Inquiry Skills strand will provide such an impetus to move to a more inquiry-based practice that better represents the way science works to generate and validate knowledge. As with previous curriculum led attempts to encourage more open and student centred pedagogies in science, this will require support for teacher professional learning, and resources including assessment approaches that nurture inquiry pedagogies. The detailed descriptions in this strand provide a good basis for doing this, if the political will exists to follow it through.

Science as a human endeavour

There has been considerable research evidence suggesting that major issues for students engaging with science is that they find the content not relevant to their lives and interests, and that the pedagogy tends to be transmissive and lacks variety. The question of pedagogy will be discussed further below, but at this point we should acknowledge that the inquiry skills strand supports a pedagogy based on student questioning and exploration that, if taken seriously, should go some way towards better engaging students with science.

It is to the human endeavour strand we need to look, regarding the question of relevance of the content to students' lives. The raising to a position of prominence of this strand is a welcome development in curriculum in Australia since it appeared in the Statements of Learning. In this Australian Science Curriculum it is interpreted to have two aspects: The nature and development of science, and The use and influence of science. The first aspect has to do with the processes by which science builds and validates knowledge. There has been a strong strand of research in the science education literature around the 'Nature of Science' (NOS) (McDonald 2010), and argumentation (Osborne, 2006), based on the notion that in order to engage with science ideas as either citizens or scientists, people need to understand the way evidence is used in science to build and test theories, the ways models and theories operate to make sense of the world, and how they are subject to rigorous evidential requirements as they are developed and refined, and occasionally replaced. We see the importance of citizens having these understandings when science becomes critically involved in major social and cultural debates, and in relation to the so called 'culture wars' that have sprung up in academia and around government policy making in recent times. Thus, an understanding of the nature of theory and evidence in science is needed to engage meaningfully in developing informed opinion on evolution as a theory, for instance, or on climate change, or at a more personal level on decisions regarding alternative therapies and the nature of medical evidence. In a meta analysis of studies of citizens interacting with science in a variety of aspects of their lives, Ryder (2001) concluded that the most important knowledge they needed was not disciplinary content knowledge, but rather knowledge about science; the way it works (see Tytler, 2007).

This first aspect of Science as a Human Endeavour addresses what Roberts (2007) calls Scientific Literacy Vision I, concerning 'within science' matters. His Scientific Literacy

Vision II looks outward at situations in which science has a role, such as decision making about socio-scientific issues. In Vision II thinking, goals for school science should be based on the knowledge and skill sets that enable students to approach and think about situations as a citizen well informed about science would. (Roberts, 2007, p. 9)

Vision II thinking aligns with the second aspect of the strand, the use and influence of science. This aspect aligns with a very long history in science curriculum advocacy for inclusion of a 'Science-Technology-Society' focus or a 'Science for all' purpose that is concerned not just with inculcating the canonical concepts of science or its methods, but widening it to include the way science interacts with society and technology. Research into this way of working includes the effectiveness of context based approaches to teaching where content is situated within real world situations and issues -- a strong strand in curriculum writing in Australia -- and where students critically engage with socio-scientific issues including sustainability issues, and ethical issues.

The Science as a Human Endeavour strand, therefore, has a strong justification in current thinking about the purposes of science education and about ways of engaging students in learning science. The raising of these aspects to the status of a strand within the curriculum is a welcome move, and could be key to driving the improvement in students' response to science we are so keen to see. That being said, we have concerns about the way this strand sits within the curriculum overall, and particularly with a notable silence in the way the strand is framed.

First, there is no clear vision for how these three strands are envisaged to work together in planning teaching and learning sequences. In the discussion on integrating the strands, early in the document, it is said that 'The content of the Science Understanding strand will inform students' understanding of contemporary issues, such as climate change…', arguably implying a priority for the understanding strand and an 'application' status for these socio-scientific issues. Yet these human endeavour aspects of science are precisely the vehicle through which the science can be made meaningful for students, and the power of the strand will be best realised through situating science learning within socio -scientific contexts, and allowing full play to the interacting roles of science knowledge and its strength and limitations, personal and social values, and technology. This is the logic behind Vision II scientific literacy. This tension between the status of the content and the role of context is very familiar in curriculum writing (see for instance Hart, 2000, 2001), and finding powerful ways to integrate the three strands is critical if we are to create a curriculum that truly engages students with science ideas and ways of thinking (Tytler, 2007). The contextualising statements for each year level should provide an opportunity to indicate ways that the strands work together, but in fact these statements are mostly concerned with describing the understanding strand with some references to the inquiry skills strand. There is practically no mention of the human endeavour strand in these framing statements, and only superficial reference in the achievement standard statements. In this current version of the curriculum, this lack of clear vision as to how the strands might be powerfully integrated is an opportunity lost. We only hope that in developing resources to support the curriculum, more imagination and commitment will be shown to developing coherent and rich units of work that draw together these three strands. We need, in this curriculum, a shift in emphasis from Roberts' Vision I to a Vision II scientific literacy emphasis.

The second concern with the human endeavour strand relates to the almost complete lack of reference to values in the document, including values relating to sustainability. Recent research into student attitudes and engagement with science has characterised this in terms of identity formation. Glen Aikenhead (2005), in arguing for a 'humanistic' science education, makes the point that for many students, especially Indigenous students, coming to appreciate science requires an identity shift whereby students come to consider themselves as science-friendly -- that 'to learn science meaningfully is identity work' (p. 117). This notion also underpins the work of Schreiner and Sjeberg (2007) in exploring the finding that students in developed countries have increasingly negative attitudes to science.

They argue that traditional approaches to teaching science as value free and concerned with technologies is at odds with the values of contemporary youth, particularly girls. There is evidence that girls in particular relate better to a science education that focuses on the values of science in helping solve human problems, be they global or personal (see Tytler et al., 2008).

We would argue that there is little point, from a scientific literacy perspective, in having students achieve science understandings if they do not develop the disposition to use these in their lives. The first aim in this curriculum document is that students develop "an interest in science as a means of expanding their curiosity and willingness to explore, ask questions about and speculate on the changing world in which they live". Yet there is no representation within any of the strands of such dispositions. The human endeavour strand focuses on students understanding how science operates, but makes no mention of how science might be valuable to them personally, or how they might be disposed to develop or use science knowledge. Granted that assessing dispositions is not straightforward, but a model can be found within the international PISA tests for assessing interest, and there are models in Australia where this is done. For instance, the NSW curriculum has a values and attitudes domain with outcomes such as 'exhibits curiosity and responsiveness to scientific and technological ideas and evidence'.

While the Australian curriculum talks of values in passing in the introduction, a search for the word in the document shows scant mention in the content descriptions or year level descriptions.

The same is true for 'ethics' and 'sustainability'. Yet in most current state documents there is a commitment to values and sustainability, for instance:

* New South Wales has a values and attitudes domain with a continuum of dispositional outcomes, within the skills domain there is a strand on working cooperatively, and in unit planning the notion of 'context' is central.

* The South Australian document has many references to sustainability and values embedded in the outcome statements, such as 'debates the value of species diversity and the ethics of human intervention', and has explicit reference to essential learnings such as curiosity, confidence and connectedness with others.

* Western Australia has an 'acting responsibly' strand: "Students make decisions that include ethical consideration of the impact of the processes and likely products of science on people and the environment".

* Each of the knowledge strands in the Tasmanian essential learnings has an outcome focused explicitly on ethics and sustainability, such as "Humans use materials and this raises ethical and sustainability issues".

Thus, when it is becoming apparent through research that engagement of all students with science ideas requires explicit attention to values and dispositions, the Australian Science Curriculum is seen to be regressive in this respect, turning its back on an important feature of current state curricula. If we are to engage all students with science and pursue an agenda of scientific literacy for all students, then we need to hope that state curriculum writers interpret and value add to this curriculum in developing curriculum resources and support that explicitly focus on enriching the positioning and content of the human endeavour strand.

The third concern with the human endeavour strand is its only partial success with a clear developmental sequence of content descriptions. In the nature and development of science sequence the move from developing explanations on the basis of evidence (Year 5/6) to scientific knowledge changing with new evidence (Year 7/8) to notions of constant model refinement (Year 9/10) is very well framed. On the other hand, in the same substrand we move from knowledge contributions of other cultures (Year 5/6) to notions of inter-disciplinarity (Year 7/8) to links with technology (Year 9/10) which is hard to see as a legitimate sequence. Do we really only talk about Indigenous knowledge in primary schools, and not look at science-technology links until Year 9? This is the same topic arbitrariness that will cause problems with the understanding strand. Ultimately, the status of the human endeavour strand will depend on shared understandings of its significance as part of scientific literacy, of how student thinking in this domain progresses, and how it can be assessed. The ACARA document is a worthy start, but further work is needed on the strand.

Pedagogical implications: Issues and possibilities

Some direction for teaching and learning is given within the document. Emphasised is an inquiry-based approach that incorporates exploration, explanation and application in line with constructivist principles of teaching and learning. Context is incorporated as the means by which the curriculum should be made relevant. Open-inquiry opportunities for students at all phases of the curriculum are promoted. Diagnostic, formative, and summative assessment is emphasised, as well as national testing regimes. Teachers are expected to tailor their teaching to the achievement levels of students, and are encouraged to teach across a number of year levels if needing to differentiate the curriculum to meet the diversity of student achievement levels in their class.

To what extent can this pedagogical direction foster innovation in curriculum development and pedagogy at the local level? A number of issues and possibilities arise specific to the Science context.

In many primary schools, classes are often composite classes, such as Year 1/2, 3/4, 5/6. In most of the state curriculum frameworks students are expected to meet the standards over a two-year period. The move to single year levels in the Australian Curriculum has implications for school structure, with some schools already introducing single year levels in anticipation of its implementation.

In schools where science is taught by specialists, or as part of a rotation of specialist classes taught by generalist classroom teachers, composite classes may be regrouped into individual year levels to deal with age appropriate content. But in many schools, science is currently taught by the generalist classroom teacher as part of the integrated program, within composite classes with multiple year levels. In such situations, a unit may be devoted to specific science concepts, such as simple machines, or the science may be integrated with other subject areas within an integrated theme such as sustainability. In this circumstance, schools will need to make decisions about how to respond to the new curriculum structure.

Some schools already have composite classes that span multiple outcome levels, such as Years 4/5, or 4/5/6, depending on enrolment profiles, so have strategies for dealing with these issues, such as by differentiating the curriculum or by the use of ability groupings, strategies often used in mathematics and English. In science, however, it can be difficult to differentiate learning tasks to cater for the different achievement levels of students within a single class, particularly if the curriculum is structured around discrete topics. In the Australian Curriculum, there appears to be tighter prescription of topics built around particular science ideas, such as Chemical change involves substances reacting to form new substances. While the document encourages tailoring learning to students' achievement levels, differentiation of the curriculum within a topic is difficult due to the tight prescription of topics to year levels, e.g. light is taught in Year 5, but not Year 4 or 6, so students cannot move between levels. There does, however, appear to be scope for teachers to draw content from the other two strands from other year levels in order to build appropriate teaching programs. Some Year 6 students, for example, may be more independent in posing and investigating questions and therefore operate at the Year 7 level, while others may require more assistance. Differentiating the curriculum has been an on-going issue in science, so if such approaches to curriculum development and pedagogy are to occur, teachers will need to be supported to plan for such differentiation.

A number of national publications provide examples of cross curriculum units of work, that are consistent with the thrust of this curriculum. Primary Connections (suitable for primary schools) and Science By Doing (suitable for secondary schools) provide published units of work based around big ideas. The website for these publications has mapped the units against the three Strands of the National Curriculum.

Summary

There are a number of positive contributions that the Australian Science Curriculum can make to conversations around innovative and exemplary science classroom practice. In particular, the framing statements at the beginning of the document that describe the Overarching Ideas, Responding to Diverse Learners, and the General Capabilities provide useful frameworks for teachers to build science programs. The three strands provide a strong ;basis for enlivening science pedagogy and engaging students in meaningful learning. In particular, the strong emphasis on inquiry as a pedagogical stance, and the addition of Science as a human endeavour has the capacity to situate science into students' current and future lives as consumers and producers of science knowledge. There are, however, some issues with the document around details of the understanding strand, limitations in the conceptualisation of the human endeavour strand, and a coherent and convincing model for how these three strands should be integrated to produce coherent and engaging classroom programs. A lot will depend on the development of assessment approaches that can adequately reflect high order knowledge in the three strands. A lot will depend on the imagination of writers who respond to this curriculum in designing programs. A lot will also depend on the resources and teacher professional learning arrangements put in place to support innovation around these ideas.

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