

National Science Curriculum: Initial advice

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National Curriculum Board's consultative process

Determining the form of the national curriculum

1 The National Curriculum Board is committed to an open development process with substantial consultation with the profession and the public. The Board began its consultation with the publication on its website (www.ncb.org.au) of *National Curriculum Development Paper*, a discussion paper in which it described the context of its work and set down a set of questions that it said it needed to answer to determine the kind of curriculum it would produce. That paper has been discussed at a national forum attended by 200 people on 27 June 2008 and in subsequent state and territory forums.

2 In the light of these discussions and its own further work the Board now sets down answers to its questions in the document *Shaping the National Curriculum: a Proposal for Discussion*. That does not mean, however, that discussion is closed. The paper is posted on the Board's website with an invitation to anyone interested to provide comment and advice during Term 4, 2008¹. After this time, the Board will determine its final recommendations and post them on its website in Term 1, 2009.

Developing the scope and content of each national curriculum

3 The Board has also begun work on the shape of the national curriculum in English, mathematics, the sciences and history. For each, the Board recruited a writer who has worked with a small advisory group to draft a relatively brief initial advice paper that provides a rationale for students studying the curriculum and a broad scope and sequence of material to be covered over the years Kindergarten to year 12.

4 This approach will facilitate a discussion of the key issues in each curriculum before any detailed curriculum development commences. The first discussions will be held in the following national forums attended by 150-220 people:

| | |
|---------------------------|--------------------|
| Monday 13 October 2008 | <i>Science</i> |
| Tuesday 14 October 2008 | <i>Mathematics</i> |
| Wednesday 15 October 2008 | <i>History</i> |
| Friday 17 October 2008 | <i>English</i> |

5 At the forums there will also be some discussion about cross-curriculum learnings, including literacy and numeracy. Feedback from the forums will form part of the consultative process that will ultimately lead to more focused consultation about literacy and numeracy as a strong foundation for all learning, as outlined in the Board's remit to develop national curriculum.

6 On the day after each forum a small group of nominees from the relevant subject associations will meet with the authors and staff from the Office of the National Curriculum Board to provide their interpretation of the discussion in the forum and its implications for developing the curriculum. More detailed papers will be posted on the Board's website with an invitation to anyone interested to provide comment and advice in the period to 28 February 2009. After that, the Board will post on its website its final recommendations to guide curriculum development.

¹ Individuals can register on the website to receive email alerts when any new material is posted, particularly material on which comment and advice are invited.

National Curriculum Board members

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Science advisory group

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Scientist

Professor Denis Goodrum biography

Denis Goodrum has been involved in many national and international activities in science education. In 1998 he was a visiting scholar at the National Research Council in Washington DC working on a project examining inquiry and the National Science Education Standards.

During the nineties he was Project Director of the National Primary School Project that was underwritten by the Australian Academy of Science. This project resulted in the curriculum resource Primary Investigations and an associated professional development model and package. In 2000 he led a research team that completed a significant and extensive national study for the federal government into the status and quality of teaching and learning of science in Australian schools. Other national projects he has lead include:

- Collaborative Australian Secondary Science Project (CASSP) that evaluated a teacher change model through the development of integrated curriculum and professional development resources.
- Science by Doing - concept plan
- Australian School Science Education: National Action Plan 2008 - 2012.

He has been a consultant for numerous projects including the Science Learning Objects for the Learning Federation, ASISTM, SEARS, NAP- SL and the WA Monitoring Standards.

He has extensive administrative experience in so far as he has carried out the roles of Head of Department, Head of School, and Dean of Faculty within the university sector. Recently he stood down as Dean of the Faculty of Education at the University of Canberra. He has served on numerous state and national Boards including Board of the Australian Deans of Education, Qwestacon, Scitech and the ACT Curriculum Renewal Taskforce.

Besides managing large national projects he has also been responsible for a variety of international projects including a Mauritius teacher education project. Other countries with which he has had professional involvement include Thailand, China, Malaysia, Singapore, Nigeria, Seychelles, Burma, USA Maldives, Philippines, Botswana, Canada and United Kingdom.

Science National Curriculum: Initial advice

Introduction

Science is a way of answering questions about the natural world. The history of science is built upon questions, and more questions, resulting from observations and the gathering of evidence. The answers to these questions form the body of knowledge that we commonly call science. This body of knowledge is continually changing, and in recent years rapidly increasing. The process of building this knowledge is as important as the knowledge itself because the journey of discovery reveals much along the way.

The spirit of discovery and innovation is a long-established Australian tradition. Over the past 200 hundred years Australian innovation, such as Charles Potter's flotation process which transformed the mining industry and Dr Alan Wash's atomic absorption spectrophotometer, which changed forever how things like blood and water were analysed, shaped the world in many fields for many years. The rewards for Australia and Australians have been rich, with major advances in health, quality of life, industry and economic prosperity. The rapidly developing information age is changing the rules for economic security and social advancement. Knowledge, ideas and innovation are becoming the world's most valuable commodities. The national science curriculum will play an important role in fostering the early development of our future scientists. It will underpin the quality and level of our knowledge, ideas and innovation and our ability to convert them into real economic and social benefits for all Australians and the world.

Drawing from the *Statements of Learning for Science* (Curriculum Corporation 2006) a science curriculum could be well based on three key elements:

1. Science as a way of knowing through inquiry

It includes posing questions, planning and conducting investigations, collecting and analysing evidence and communicating findings. It is concerned with evaluating investigations and claims and making valid conclusions. It also recognises that scientific explanations change as new or different evidence becomes available from investigations. (p. 5)

2. Science as a human endeavour

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-informed 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 (p. 4).

3. Scientific knowledge

It describes opportunities to engage with and increase understandings of scientific concepts, explanations and theories. These concepts, explanations and theories are drawn from physics, chemistry, biology and geosciences (p. 5).

All three elements of science are important and should be evident, albeit to different degrees, across all stages of schooling.

Purpose of school science education

Australia is a scientifically and technologically advanced nation. It is imperative that its future citizens have an understanding of science so that personal and societal decisions can be made on the basis of evidence and reason.

The purpose of school science is to develop science competencies by which students can:

- understand more about science and its processes
- recognise its place in our culture and society
- use it in their daily lives.

It could be argued that developing these science competencies is a basic need for effective citizenship. By focusing on science competencies, school science not only prepares students for citizenship, but provides a solid platform for more specific science pathways. These pathways may include more specialised, discipline-based study in senior secondary school that lead to science courses at university or more technical and vocational education and training, leading to science-related careers.

By the end of the compulsory years of science study it is expected that students would be able to demonstrate the following attributes of scientifically knowledgeable people:

- they are interested in and understand the natural world around them
- they engage in discussions of and about science
- they are sceptical and questioning of the claims made by others
- they can identify and investigate questions and draw evidence-based conclusions
- they can make informed decisions about the environment and their own health and well being.

Essentially the focus is on what one could describe as 'science for life'. It is a science that has meaning for the everyday experiences of students and people. Science education should acknowledge the interaction between science and social values in the many debates about the applications of science.

Becoming scientifically competent is a cumulative process that begins with early childhood explorations and continues throughout schooling. The kinds of teaching and learning strategies that best assist students to develop their science skills and competencies will vary according to the age and capabilities of the student, but all levels of schooling should contribute to its development. A focus on developing scientific competencies has implications for the way science is taught. A summary of the kinds of pedagogical changes required to promote scientific competencies is shown in Appendix 1.

In a recent evaluation of science learning in United Kingdom schools, the report by Science Inspectors concluded that the core factor in those schools with the highest or most rapidly improved science learning was their commitment to science inquiry. In those schools students were given the opportunity to pose questions and design and carry out investigations for themselves (Ofsted, 2008). Science inquiry is an important dimension of developing scientific competencies.

Science curriculum issues

Preparing a national science curriculum that will help school students develop their scientific competencies alongside their acquisition of science knowledge requires attention to four issues.

1. Selection of science content (knowledge, skill, understanding and values)

There is a consistent criticism that many of the problems and issues in science education arise from the structure of science curricula which tend to be knowledge-heavy and alienating to a significant number of students.

A curriculum that covers an extensive range of science ideas hampers the efforts of even the best teachers who attempt to provide engaging science learning for their students. The effect of such knowledge-laden curricula is for teachers to treat science concepts in a superficial way as they attempt to cover what is expected in the curriculum. Rather than developing understanding, students therefore have a tendency to rely on memorisation when taking tests of their science learning. The challenge is to identify the science concepts that are important and can be realistically understood by students in the learning time available.

One of the realities faced in science education is that scientific knowledge is rapidly increasing. While this is valuable for our society, it adds to the pressure on the science curriculum. There is a reluctance to replace the old with the new. Rather, there is a tendency to simply add the new science ideas to the traditional ones. Accompanying this desire to retain the traditional knowledge base is a feeling that understanding this content exemplifies intellectual rigor. Obviously such a situation is not sustainable. The consequence is that many students are losing interest in science.

The question then needs to be asked: what is important in a science curriculum? This paper argues that developing science competencies is important, understanding the big ideas of science is important, exposure to a range of science experiences relevant to everyday life is important and understanding of the major concepts from the different sciences is important.

It is also acknowledged that there is a core body of knowledge and understanding that is fundamental to the understanding of major ideas.

The paper also proposes that it is possible to provide flexibility and choice about the content of local science curriculum. The factors that influence this choice include context, local science learning opportunities, historical perspectives, contemporary and local issues and available learning resources. In managing this choice, there is a need to be conscious of the potential danger of repetition of knowledge through a student's school life and ensure repetition is minimised and that a balanced science curriculum is provided for every student.

Finally, when selecting content for a national science curriculum it is important to determine how much time can reasonably and realistically be allocated to science and within this time constraint what is a reasonable range of science concepts and skills for learning in primary and secondary school.

2. Relevance of science learning

A curriculum is more likely to provide a basis for the development of scientific competencies if it is relevant to individual students, perceived to have personal value, or is presented in a context to which students can readily relate.

Instead of simply emphasising what has been described as 'canonical science concepts', there is a need to provide a meaningful context to which students can relate (Aikenhead 2006). Furthermore, students will be better placed to understand the concepts if they can be applied to everyday experiences. To provide both context and opportunities for application takes time. To increase the relevance of science to students there is a strong case to include more contemporary (and possibly controversial) issues in the science curriculum. In doing so, it is important to note that the complexity of some scientific issues means that they do not have clear-cut solutions. Often, the relevant science knowledge is limited or incomplete so that the questions can only be addressed in terms of what may be possible or probable rather than the certainty of what will happen. Even when the risks inherent in making a particular decision are assessable by science, the cultural or social aspects also need to be taken into consideration. The school science curriculum should provide opportunities to explore these complex issues to enable students to understand that the application of science and technology to the real world is often concerned with risk and debate (Rennie 2006).

Science knowledge can be applied to solve problems concerning human needs and wants. Every application of science has an impact on our environment. For this reason, one needs to appreciate that decisions concerning science applications involve constraints, consequences and risks. Such decision-making is not value-free. In developing science competencies, students need to appreciate the influence of particular values in attempting to balance the issues of constraints, consequences and risk.

While many students perceive school science as difficult, the inclusion of complex issues should not be avoided on the basis that there is a potential for making science seem even more difficult. The answer is not to exclude contemporary issues, but rather to use them to promote a more sophisticated understanding of the nature of science and scientific knowledge.

It is important to highlight the implications of a science curriculum that has personal value and relevance to students. This means that the curriculum cannot be a 'one size fits all', but rather a curriculum that is differentiated so that students can engage with content that is meaningful and satisfying and provides the opportunity for conceptual depth. In this respect the science curriculum should be built upon knowledge of how students learn, have demonstrated relevance to students' everyday world, and be implemented using teaching and learning approaches that involve students in inquiry and activity.

Within the flexibility of a science curriculum that caters for a broad cohort of students and a range of delivery contexts, there is a need to define what it is that students should know in each stage of schooling. In this way, students can build their science inquiry skills based on an understanding of the major ideas that underpin our scientific endeavour.

3. General capabilities and science education

There is an argument, based on research within science education, that curriculum needs to achieve a better balance between the traditional knowledge-focused science and a more humanistic science curriculum that prepares students for richer understanding and use of science in their everyday world (Fensham, 2006). Beyond the science discipline area there is also pressure in some Australian jurisdictions to develop a broader general school curriculum that embraces the view of having knowledge and skills important for future personal, social and economic life. While there is much value in such futuristic frameworks, there is the danger that the value of scientific understanding may be diminished. Unless the details of the general capabilities refer specifically to science content, the importance of science may be overlooked and the curriculum time devoted to it decrease.

The science curriculum can readily provide opportunities to develop these general capabilities. Such general capabilities as thinking strategies, decision-making approaches, communication, use of information and communication technology (ICT), team work and problem solving are all important dimensions of science learning.

There is an increasing number of teachers who will require assistance to structure their teaching in ways that enable students to meld the general life capabilities with the understanding and skills needed to achieve scientific competencies. Such assistance will be found in the provision of quality, adaptable curriculum resources and sustained effective professional learning.

4. Assessment

When a curriculum document is prepared there is an expectation that what is written will be what is taught and what is assessed. Unfortunately, there is sometimes a considerable gap between intended curriculum, the taught curriculum and the assessed curriculum; what can be assessed often determines what is taught. This disconnect is a result of the different pressures and expectations in education system. An obvious goal in curriculum development is that the intended, taught and assessed dimensions of curriculum are in harmony.

The importance of assessment in curriculum development is highlighted in the process referred to as 'backward design' in which one works through three stages from curriculum intent to assessment expectations to finally planning learning experiences and instruction (Wiggins & McTighe, 2005). This process reinforces the simple proposition that for a curriculum to be successfully implemented one should have a clear and realistic picture of how the curriculum will be assessed.

Assessment should serve the purpose of learning. Classroom assessment, however, is often translated in action as testing. It is unfortunate that the summative end-of-topic tests seem to dominate as the main tool of assessment. Senior secondary science assessment related to university entrance has long reinforced a content-based summative approach to assessment in secondary schools. To improve the quality of science learning there is a need to introduce more diagnostic and formative assessment practices. These assessment tools help teachers to understand what students know and do not know and hence plan relevant learning experiences that will be beneficial. Summative testing

does have an important role to play in monitoring achievement standards and for accountability and certification purposes, but formative assessment is more useful in promoting learning. Assessment should enable the provision of detailed diagnostic information to students. It should show what they know, understand and can demonstrate. It should also show what they need to do to improve.

It should be noted that the important science learning aspects concerning attitudes and skills as outlined in the paper cannot be readily assessed by pencil and paper tests. For that reason, it is important to emphasise the need for a variety of assessment approaches. While assessment is important, it should not dominate the learning process.

Structure of the curriculum

There is value in differentiating the curriculum into various parts that are relevant to the needs of the students and the school structure (Fensham, 1994). In regard to the school structure, the nature of the teacher's expertise becomes a factor to consider. For early childhood teachers, their expertise lies in the understanding of how children learn. Secondary science teachers have a rich understanding of science while senior secondary teachers have expertise in a particular discipline of science. Each part would have a different curriculum focus. The four parts are:

- early childhood
- primary
- junior secondary
- senior secondary.

Developing scientific competencies takes time and the science curriculum should reflect the kinds of science activities, experiences and content appropriate for students of different age levels. In sum, early science experiences should relate to self awareness and the natural world. During the primary years, the science curriculum should develop the skills of investigation, using experiences which provide opportunities to practice language literacy and numeracy. In secondary school, some differentiation of the sub-disciplines of science may be appropriate, but as local and community issues are interdisciplinary, an integrated science may be the best approach. Senior secondary science curricula should be differentiated, to provide for students who wish to pursue career-related science specializations, as well those who prefer a more general, integrated science for citizenship.

The main aspects of the first three parts for the proposed structure of the science curriculum are outlined in the table on page 12.

1. Early Childhood

Curriculum focus: awareness of self and the local natural world

Young children have an intrinsic curiosity about their immediate world. They have a desire to explore and investigate the things around them. Purposeful play is an important feature of their investigations. Observation is an important skill to be developed at this time, using all the senses in a dynamic way. Observation also leads into the idea of order that involves comparing, sorting and describing.

2. Primary

Curriculum focus: recognising questions that can be investigated scientifically and investigating them

During the primary years students should have the opportunity to develop ideas about science that relate to their life and living. A broad range of topics is suitable including weather, sound, light, plants, animals, the night sky, materials, soil, water and movement. Within these topics the science ideas of order, change, patterns and systems should be developed.

In the early years of primary school, students will tend to use a trial and error approach to their science investigations. As they progress through their primary years, the expectation is that they will begin to work in a more systematic way. The notion of a 'fair test' and the idea of variables will be developed, as well as other forms of science inquiry. The importance of measurement will also be fostered.

3. Junior secondary

Curriculum focus: explaining phenomena involving science and its applications.

During these years, the students will cover topics associated with each of the sciences: earth and space science, life science and physical science. Within these topics it is expected that aspects associated with science for living, science inquiry and contemporary science would be integrated in the fields of science. While integration is the more probable approach, it is possible that topics may be developed directly from each one of these themes. For example, there may be value in providing a science unit on an open science investigation in which students conduct a study on an area of their choosing.

While there may be specific topics on contemporary science aspects and issues, teachers and curriculum resources should strive to include the recent science research in a particular area. It is this recent research that motivates and excites students.

In determining what topics students should study from the broad range of possibilities, it is important to exercise restraint and to avoid overcrowding the curriculum and providing space for the development of students' science competencies alongside their knowledge and understanding of science content. Topics could include states of matter, substances and reactions, energy forms, forces and motion, the human body, diversity of life, ecosystems, the changing earth and our place in space. The big science ideas of energy, sustainability, equilibrium and interdependence should lead to the ideas of form and function that result in a deeper appreciation of evidence, models and theories.

There are some students ready to begin a more specialised program science in junior secondary and differentiation as early as Year 9 may need to be considered to extend and engage these students' interest and skills in science.

4. Senior Secondary

There should be at least three common courses across the country: physics, chemistry and biology. There could also be one broader-based course that provides for students wanting only one science course at the senior secondary level. It could have an emphasis on applications. The integrating themes of science for life, scientific inquiry and contemporary science should be embedded into all these courses where realistically possible.

Other specialised courses could also be provided. Existing courses in the states and territories are among the possibilities available. National adoption would improve the resources to support the individual courses.

A proposed structure for the science curriculum

| | Curriculum focus | Developing science competencies | Sources of interesting questions and the related scientific knowledge | Relevant big ideas of science |
|-------------------------------------|--|--|---|---|
| Early childhood | Awareness of self and the local natural world | <ul style="list-style-type: none"> • Asking questions and beginning to investigate • Nurturing curiosity, excitement and wonder | Everyday life experiences involving science at home and in nature | <ul style="list-style-type: none"> • Importance of observation and play |
| Primary | Recognising questions that can be investigated scientifically and investigating them | <ul style="list-style-type: none"> • Gathering evidence and using it in scientific investigations • Confident about representing data and providing scientific answers to others in a simple manner | Wide range of science phenomena that provide questions of interest and public importance to primary school students. | <ul style="list-style-type: none"> • Order • Change • Patterns • Systems |
| Secondary (compulsory years) | Explaining phenomena involving science and its applications | <ul style="list-style-type: none"> • Understanding the science of everyday experience • Providing deeper explanations involving the major concepts of science and their models • Developing an interest in science for future study and possible employment | Simple everyday science phenomena and the major concepts from the physical, biological, earth and other sciences and from the applications of science that shape the personal and public worlds of adolescents. | <ul style="list-style-type: none"> • Energy • Sustainability • Equilibrium and interdependence • Form and function • Evidence, models and theories |

Acknowledgements

This paper draws heavily on the work contained in the two-volume *Australian School Science Education National Action Plan 2008-2012* (Goodrum & Rennie 2007, Rennie & Goodrum 2007). The report provides an up-to-date synthesis of national and international research on school science education. In developing the Action Plan the authors accepted advice from major stakeholders in Australian science education within a relatively volatile education environment. The report has been endorsed in principle by all jurisdictional education systems. As such, it is a solid foundation for preparing a framing paper for a national curriculum in the sciences.

Another recent report that was valuable in preparing this paper was *Re-imagining Science Education: Engaging students in science for Australia's future* (Tytler, 2007). The genesis for this report was a national conference entitled *Boosting Science Learning- What will it take?* held in Canberra, 2006. The conference, sponsored by the Australian Council for Educational Research, brought together many people from the different science education interest areas with the focus of improving school science learning.

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Appendix 1: Changes in emphasis required to teach for scientific competencies

Teaching for scientific competencies requires:

| Less emphasis on | More emphasis on |
|--|--|
| memorising the name and definitions of scientific terms | learning broader concepts that can be applied in new situations |
| covering many science topics | studying fewer but more fundamental concepts |
| learning science concepts as abstraction | learning science concepts in contexts that are meaningful and excite interest |
| presenting science by talk, text and demonstration | guiding students in active and extended student inquiry |
| asking for recitation of acquired knowledge | providing opportunities for scientific discussion among students |
| individuals completing routine assignments | teams working cooperatively to investigate problems or issues |
| activities that demonstrate and verify science content | open-ended activities that investigate relevant science questions |
| providing answers to teacher's questions about content | communicating the findings of the student investigations |
| science being interesting for only some students | science being interesting for all students |
| assessing what is easily measured | assessing learning outcomes that are most valued |
| assessing recall of scientific terms and facts | assessing understanding and its application to new situations, and skills of investigation, data analysis and communication |
| end-of-topic multiple choice tests for grading and reporting | ongoing assessment of work and the provision of feedback that assists learning |
| learning science mainly from textbooks provided to students | learning science actively by seeking understanding from multiple sources of information, including books, Internet, media reports, discussion, and hands-on investigations |

(From Goodrum et al., 2001, p. 168. This format and some parts of the figure are derived from the *National Science Education Standards*, National Science Council, 1996, pp. 52, 100, 113.)