National Science Curriculum: Framing paper

For consultation: November 2008 – 28 February 2009

CONTENTS

PREAMBLE

Purpose of the *National Science Curriculum: Framing paper*

1 The *National Science Curriculum: Framing paper* proposes broad directions for what teachers should teach and young people should learn in the national science curriculum from Kindergarten[1] to Year 12.

2 The purpose of this paper is to generate broad-ranging discussions about curriculum development. The paper is posted on the National Curriculum Board's website (www.ncb.org.au) with an invitation to all those interested to provide feedback and advice up to 28 February 2009.

3 The Board will then examine all feedback and determine its final recommendations to guide curriculum development.

Process to develop the *National Science Curriculum: Framing paper*

4 The National Curriculum Board began its consultation with the publication of the *National Curriculum Development Paper* on its website. This paper described the context of its work and set down questions that needed to be answered to determine the kind of curriculum that would be developed.

5 *The Shape of the National Curriculum: A Proposal for Discussion* was developed following feedback from the 'Into the Future: National Curriculum Board Forum' and state and territory consultation forums. Appendix 1 provides details about its principles and specifications for curriculum development. This paper is posted on the Board's website with an invitation to anyone interested to provide feedback during Term 4, 2008.

6 The Board began work on framing the national science curriculum by recruiting a writer who worked with a small advisory group (see Appendix 2) to draft an initial advice paper that provided a broad scope and sequence from Kindergarten to Year 12.

7 This initial advice paper was discussed at a national forum in October. On the day after the forum a small group of nominees from the Australian Science Teachers' Association met with the writer to discuss the feedback from the forum and its implications for developing the curriculum.

8 The *National Science Curriculum: Framing paper* is built on this initial advice, advisory group feedback, submissions through the Board's website, individual responses by academics and teachers, responses from the national and state science forums, and responses received by email and letters.

9 This *National Science Curriculum: Framing paper* is best read in conjunction with *The Shape of the National Curriculum: A Proposal for Discussion* to provide a context for the shape of the curriculum overall. The framing paper focuses on what the content of the national science curriculum might be; assessment and pedagogy, although key considerations for any curriculum, are addressed only briefly in the paper.

[1] 'Kindergarten' refers to the first year at school. In some jurisdictions this is called 'Reception' or 'Preparatory'.

Providing feedback about the *National Science Curriculum: Framing paper*

10 The Board welcomes feedback on this paper. Feedback questions are included in Appendix 3 and there are several ways to participate. Feedback can be emailed to *feedback@ncb.org.au* and written feedback can be mailed to: National Curriculum Board Feedback, PO Box 177, Carlton South, Victoria 3053.

11 From 21 November online feedback for this paper can be submitted through the Board's website link:

http://www.ncb.org.au/get_involved/subscribe/ways_of_participating.html

Register from this link. Once you have joined, a username and password provide easy access to online surveys, discussions and summaries of feedback comments. This is an opportunity to be fully involved and up-to-date with national curriculum development.

INTRODUCTION

12 Science is a way of answering questions about the natural world. The body of scientific knowledge and understanding has been built upon questions, and more questions, resulting from observations and the gathering of evidence. This body of knowledge and understanding is continually changing, and in recent years it has been rapidly increasing. The process of building scientific knowledge is as important as the knowledge itself.

13 The spirit of science inquiry and innovation is a long-established Australian tradition. Over the past two hundred years Australian innovation has had worldwide impact. These innovations range from Charles Potter's flotation process that transformed the mining industry, to the research of Nobel laureates Barry Marshall and Robin Warren, who found that stomach ulcers could be cured by antibiotics, easing the suffering of millions of people around the world. The rewards for Australia and Australians have been rich, with major advances in health, quality of life, industry and economic prosperity.

14 Knowledge, ideas and innovation are becoming the world's most valuable commodities, and scientific knowledge, ideas and innovation contribute significantly to real economic and social benefits for Australia. The national science curriculum will play an important role in fostering the early development of our future scientists and people in science-related industries, as well as developing the science capabilities of its citizens.

15 Becoming scientifically capable is a cumulative process that begins in early childhood and continues throughout schooling. The kinds of teaching and learning strategies that best assist students to develop science capabilities and understanding will vary according to the different needs and interests of young people. This has implications for the way science is taught.

16 In a recent evaluation of science learning in United Kingdom schools, the report by science Inspectors concluded that the main factor in the 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). The ability to pose and investigate questions in science inquiry is an important dimension of developing scientific capabilities.

AIMS

17 The main objective of school science education is to develop young people's science capabilities. It is imperative that Australia's future citizens have scientific knowledge and understanding that enable them to make personal and societal decisions on the basis of evidence and reason. For example, people who are scientifically capable can make informed decisions about the products they buy, the food they eat, the environment in which they live or the lifestyle they adopt.

18 By the end of the compulsory years of school science it is intended that students should be able to demonstrate:

- an interest in and understanding of the natural world
- the ability to engage in communication of and about science
- scepticism and questioning of the claims made by others

- identification and investigation of questions and drawing together evidence-based conclusions
- the ability to make informed decisions about the environment, and their own health and wellbeing.

19 As well as preparing students for active citizenship, school science should also provide a foundation for more specific science pathways. These pathways may include more specialised, discipline-based study in senior school science that lead to science courses at university, or more technical and vocational education and training, leading to science-related careers.

20 An advanced science education will mean that young Australians have the opportunity to better understand the rapidly changing world around them and have the educational foundation to pursue a career in science, engineering or technology. There are strong economic reasons for investing in developing scientifically capable people. Australia's success as a knowledge economy is dependent on a highly skilled, informed and scientifically capable workforce. The 'science for life' approach translates into a science curriculum that has three important elements: science understanding, science inquiry skills, and science as a human endeavour.

TERMS USED IN THIS PAPER

21 **Science capabilities** are the skills and capacities that enable a person to function effectively in an advanced scientific and technological society and are central to students becoming scientifically literate. The term 'scientific literacy' is well-established in the science education community, but sometimes causes confusion in the broader community (Linder, et al, 2007). For this reason, the term "science capabilities" is employed because it is commonly understood.

22 **Science inquiry** refers to the diverse ways in which scientists attempt to find answers to questions about the natural world. It also refers to the activities of students as they develop an understanding of scientific ideas. Scientific inquiry involves planning and carrying out investigations, seeking answers from a variety of sources of information (including books and the internet), making observations and subsequent predictions or propositions, and analysing data and evidence gathered personally or provided by others.

23 **Science understanding** is evident when a person selects and integrates appropriate science knowledge in ways that explain and predict other natural 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. Science knowledge represents the building blocks of science understanding but it is the dynamic nature of science understanding that will be beneficial to citizens in an ever changing world (National Research Council 1996).

24 **Science attitudes** include the valuing of evidence, the ability to suspend judgment as a consequence of little evidence, willingness to change opinion in the light of new evidence, adherence to truth and honesty, and healthy scepticism that seeks evidence before making decisions. They also include dispositions such as curiosity and a willingness to speculate about and explore the natural world.

25 **Technology** can be used to solve problems about human needs. Many technological solutions are based on science knowledge. Scientific advances are often a result of improved technology. Some understanding and use of technology is an important component of school science, because it can provide students with a context and point of relevance for science concepts. A futures-oriented curriculum must take account of the scientific applications of modern technologies.

26 **Contemporary science** can be used to emphasise current science research. Emerging areas of scientific research or of social impact, such as gene technology, climate change and nanotechnology, can be studied. Recent advances can be used in traditional science topics such as students investigating the new types of dry-cell batteries or hybrid cars when they learn about electricity.

CONSIDERATIONS

27 In the development of a national science curriculum, a number of considerations must be taken into account to inform the directions of the development process. These considerations are discussed below.

Selection of science content

28 A challenge for the national science curriculum is how to take account of the rapidly increasing body of science knowledge and not simply add more to what students are expected to know. Consideration needs to be given to what traditional knowledge should be retained in the curriculum and what new knowledge should be introduced, This consideration will need to address expectations for intellectual rigor in the curriculum, the need to avoid overloading the curriculum, and the need to improve engagement of young people in learning science.

29 It is acknowledged that there is a core body of science knowledge and understanding that is fundamental to the learning of science: however, the structures of the current implemented science curriculum tend to be knowledge-heavy and may be alienating for a number of students.

30 Similarly a curriculum that covers an extensive range of science ideas and knowledge has the potential to treat science concepts in a superficial way as teachers attempt to cover what is expected in the curriculum. The challenge, in terms of science content, is to identify the key science concepts and focus on developing understanding and skill development rather than memorisation of a great range of knowledge.

31 When selecting content for a national science curriculum it will be important to be clear about how much time can be realistically allocated to science and, within this time allocation, determine what is an appropriate range of science concepts and skills for learning in primary and secondary school.

32 Selection of content should recognise: the importance of the big ideas of science that students ought to understand in order to build a strong base of scientific knowledge; the importance of exposure to a range of science experiences relevant for each stage of

learning; and the importance of understanding the major concepts from the different sciences.

Relevance of science learning

33 The school science curriculum should aim for the development of scientific capabilities that can be achieved in contexts to which students can relate and which are relevant to individual students.

34 More contemporary (and possibly controversial) science issues should be included in the school science curriculum. Many scientific issues 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 and social aspects also need to be considered in the decision-making process.

35 The school science curriculum should provide opportunities to explore 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). The inclusion of complex issues should not be avoided on the basis that there is a potential for making science seem difficult. The idea is to use them to promote a more sophisticated understanding of the nature of science and science knowledge. Young people need to understand that decisions concerning science applications involve constraints, consequences and risks. Such decision-making is not value-free. In developing science capabilities, students learn about the influence of particular values in attempting to balance the issues of constraints, consequences and risk.

Flexibility and equity

36 The national science curriculum should provide flexibility and choice for teachers and students. The factors that influence this choice include school and community context, local science learning opportunities, historical perspectives, contemporary and local issues and available learning resources. In managing this choice, a balanced science curriculum should engage every student while catering for a broad cohort of students and a range of delivery contexts.

37 Equally, the national science curriculum should provide a common and consistent base that delivers equity of opportunity, engaging every student through to the end of the compulsory years of schooling and enabling them to make active and informed decisions about whether to pursue further study of science. Ensuring that every student learns the science knowledge, skill and understanding that enables them to actively participate in the broader community will require consideration of how to best engage every student and the way particular groups may have previously been excluded.

General capabilities

38 The science curriculum can readily provide opportunities to develop thinking strategies, decision-making approaches, communication, use of information and

communication technology (ICT), team work and problem solving. The development of these general capabilities should be taught in the context of science content.

39 It will be incumbent upon teachers to structure their teaching in ways that enable students to meld general life competencies with the understanding and skills needed to achieve scientific capabilities. Where required, teachers will be assisted to do this through the provision of quality, adaptable curriculum resources and sustained effective professional learning.

STRUCTURE OF THE CURRICULUM

Elements

40 The science curriculum should be based on three elements[2] that are interrelated:

41 **Science understanding:** Understanding of scientific concepts, explanations and theories enables people to explain and predict natural phenomena and to apply that knowledge and understanding to new situations and events. These concepts, explanations and theories are drawn from physics, chemistry, biology and geosciences.

42 **Science inquiry skills:** Science inquiry poses questions, involves planning and conducting investigations, collecting and analysing evidence and communicating findings. This element 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.

43 **Science as a human endeavour:** Science influences society through its posing of social and ethical issues. Societal challenges or social priorities influence the direction and development of scientific research. This element highlights the need for informed, evidence-based decision making about current and future applications of science where there is, or would be, an impact on society and the environment. It acknowledges that in making decisions about science and its practices, moral, ethical and social implications must be taken into account. It also 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.

44 All three elements of science are important and should be evident across each stage of schooling. In delivering the science curriculum the focus is on science understanding through the development of science concepts. The science inquiry skills and the human endeavour dimensions are embedded in the development of these science concepts.

Stages of schooling

45 Although it is proposed that the curriculum will be represented year by year this document provides an outline across four stages of schooling:

[2] Drawn from Curriculum Corporation 2006

Stage 1, which typically involves students from 5 to 8 years of age

Stage 2, which typically involves students from 8 to 12 years of age

Stage 3, which typically involves students from 12 to 15 years of age

Stage 4, which typically involves students from 15 to 18 years of age.

46 Developing scientific capabilities takes time and the science curriculum should reflect the kinds of science activities, experiences and understanding appropriate for students of different ages. 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 reinforce language, literacy and numeracy relevant to science. In secondary school, some differentiation of the sub-disciplines of science is appropriate, although as many science issues are interdisciplinary, an integrated approach to science education is also appropriate. The senior secondary science curriculums should be differentiated into courses, to provide for students who wish to pursue career-related science specialisations, as well those who prefer a more general, integrated science for citizenship. A proposed structure for a K-12 curriculum is provided below.

Table 1: A proposed structure for the K–12 science curriculum

	Curriculum focus	*Sources of interesting questions and the related science understanding*	*Relevant big ideas of science*
Stage 1	Awareness of self and the local natural world	Everyday life experiences involving science at home and in nature	Exploration Observation Order Questioning & speculating
Stage 2	Recognising questions that can be investigated scientifically and investigating them	Wide range of science phenomena that provide questions of interest and public importance to primary school students	Change Patterns Systems Cause & effect Evidence & explanations
Stage 3	Explaining phenomena involving science and its applications	Simple everyday science phenomena and the major concepts from the physical, biological, earth and space sciences and from the applications of science that shape the personal and public worlds of adolescents	Energy Sustainability Equilibrium & interdependence Form & function Evidence, models & theories
Stage 4	Opportunity to pursue science subjects relevant to interests and future intentions	Separate subjects: • Physics • Chemistry • Biology • Environmental science • Science for life & work	All of the above would be embedded in the different science subjects.

This structure is examined further in the following sections.

47 In the following sections science inquiry skills and science knowledge are outlined for each stage of learning. The element of science as a human endeavour is not presented in a developmental way in these sections. It is expected that this element will be embedded in science activities. In the same way, the idea of relevance is emphasised in this curriculum.

Relevance will be reflected in the different contexts that are used by teachers to introduce and develop the scientific concepts.

48 The relevant big ideas of science and science inquiry are introduced at each stage. Each subsequent stage builds on the big ideas of the previous stage, enabling students to accumulate the knowledge base for depth of understanding.

Stage 1 (typically from 5 to 8 years of age)

Curriculum focus: awareness of self and the local natural world

49 Young children have an intrinsic curiosity about their immediate world. Raising questions leads to speculation and the testing of ideas. They have a desire to explore and investigate the things around them. Exploratory, purposeful play is a central 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 describing, comparing, and sorting.

Relevant big ideas of science	*Exploration*: Investigation of objects and things around them, through purposeful play, as a precursor to more directed inquiry in later years. *Observation*: Using all five senses, to observe and gather information about the objects in the child's environment. Looking for what is the same and what is different. *Order*: Observing similarities and differences and comparing, sorting and classifying to enable children to create an order that is more meaningful to them (in a world that may well seem complex and complicated). *Questioning & speculating*: Questions and ideas about the world become increasingly purposeful. Encouraged to develop explanatory ideas and test them through further exploration.
Science inquiry skills	• asking questions and beginning to investigate • exploring, curiosity and wonder • using evidence to support ideas
Topics and major concepts	• block play and structures • using the senses • observing living things, objects and materials in the natural world • movement • comparing, sorting and classifying • developing and testing ideas

Stage 2 (typically from 8 to 12 years of age)

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

50 During these years students should have the opportunity to develop ideas about science that relate to their life and living. A broad range of topics will be explored. Within these topics, the science ideas of order, change, patterns and systems, cause and effect, and evidence and explanation should be developed.

51 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 these 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. Understanding the importance of measurement will also be fostered.

<table>
<tr><td>Relevant big ideas of science</td><td> Change: There are many changes that occur in the natural world. Some of these changes are reversible, but many are not. Changes occur in materials, the position of objects, and the growth cycles of plants and animals. These changes vary in their rate and their scale.
Patterns: Through observation one can detect similarities among objects, living things and events. These similarities form patterns that underlie the idea of regular repetition. By identifying these patterns in nature, explanations can be developed about the reasons for the patterns.
Systems: The natural world is complex but can be understood by focusing on its smaller components. Understanding develops by examining these smaller components, or parts, and how they are related. Groups of parts that work together as a whole are commonly described as systems. There are also systems within systems or subsystems. So, an animal can be regarded as a system and within the animal there can be subsystems, such as the nervous system. There are many types of systems — for example, a pond, a telephone network, machines, a school, and the solar system.
Cause and effect: One important aspect of science investigation is the study of relationships between different factors or variables. Cause and effect is an important kind of relationship. Examples of cause and effect questions are: If a plant dies, what are the factors that caused its death? If a person develops a skin rash, what has caused that rash?
Evidence and explanations: Evidence is the driving force of science knowledge. From the data derived from observation, explanations about phenomena can be developed and tested. With new evidence, explanations may be refined, or may change. </td></tr>
<tr><td>Science inquiry skills</td><td>
identifying questions that can be investigated
planning and conducting simple investigations
using tools to gather data and improve observation and measurement
using data to formulate explanations
analysing data to explain the relationships between different factors.
communicating investigations and explanations to others.
</td></tr>
<tr><td>Topics and major concepts</td><td>
characteristics of plants
characteristics of animals
pushes and pulls
growth, cycles and change
soil
water
weather
liquids and solids
processed materials
sound
light
the night sky
relationship between the earth, moon and sun
simple electric circuits
living things and the environment.
</td></tr>
</table>

Stage 3 (typically from 12 to 15 years of age)

Curriculum focus: explaining phenomena involving science and its applications

52 During these years, the students study topics associated with each of the sciences: earth and space science, biological science and physical science. It is expected that aspects associated with science as a human endeavour, science inquiry and contemporary science would be integrated within these topics. While integration is the more probable approach, it is possible that topics may be developed directly from each one of these aspects. For example, there may be value in providing a unit in which students conduct a science investigation in an area of their choosing.

53 It is important to include specific topics on contemporary science aspects and issues to enhance students' understanding of science in the world around them; and teachers and curriculum resources should ensure the inclusion of the recent science research in a particular area. It is current research and its human uses and implications that motivates and excites students.

54 In determining what topics students should study, it is important to exercise restraint and avoid overcrowding the curriculum, and so provide time to build the knowledge base that underlies science understanding. 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.

55 Some students will be ready to begin a more specialised program of science at this stage and differentiation may need to be considered to extend and engage the interest and skills of these students.

<table>
<tr>
<td>Relevant big ideas of science</td>
<td colspan="4">Energy: Energy is the basis of all activity in the natural and designed world. There are different forms of energy and energy is transferred between these forms. A guiding principle is that energy is always conserved. A challenge for humans is to use energy wisely.

Sustainability: The idea of sustainability is central to the nature of dynamic systems. A system has inputs and outputs and a variety of internal functions. The interaction of these inputs, functions and outputs determines the degree to which any system can sustain itself. The inputs include resources that may be renewable or non-renewable.

Equilibrium and interdependence: In a system there are forces and changes that act in opposing directions. For a system to be stable, these factors need to be in a state of balance or equilibrium. This equilibrium is based on the interdependence of all the components within the system. A change in one of the components can affect all components of the system because of the interrelationships between the parts.

Form and function: For objects and organisms, form and function are complementary. Form describes the nature or make up of an aspect of an object or organism, while function represents the use of that aspect. For example, the form of a particular bone in the human body is specifically suited to its use.

Evidence, models and theories: Just as evidence provides the basis of explanations, explanations are used and refined to form models and theories. Models and theories are more complex, abstract schemes or structures that provide a more detailed but tentative basis for understanding a range of evidence.</td>
</tr>
<tr>
<td>Science inquiry skills</td>
<td colspan="4">• designing and conducting a scientific investigation involving measurement and repeated trials
• gathering data from a variety of sources including books and the internet
• analysing and testing models and theories based on the evidence available.</td>
</tr>
<tr>
<td>Topics and major concepts</td>
<td>Physical sciences
• nature of matter, including particle theory
• electricity and magnetism
• heat
• forms of energy and energy transfer
• forces and motion
• acids and bases
• metals and non-metals
• elements, compounds and chemical reactions.</td>
<td>Biological sciences
• characteristics of living things
• plants and photosynthesis
• the human body
• cells and living things
• ecosystems
• evolution and the diversity of living things.</td>
<td>Earth and space sciences
• structure of the Earth and geological history
• plate tectonics and geological phenomena
• stars, galaxies and the universe.</td>
<td>Contemporary science
• nature of science
• research of an Australian scientist
• current science issues, e.g. water and its management, climate change, stem cell research, nanotechnology, gene technology
• science-related industries and professions.</td>
</tr>
</table>

Stage 4 (typically from 15 to 18 years of age)

Curriculum focus: senior secondary courses

56 Physics, chemistry, biology and environmental science should be provided in the senior secondary years. These courses will recognise the sequential nature of knowledge in the field and enable the development of depth of understanding of carefully selected key concepts, processes and contexts without overcrowding the curriculum. There should also be an additional, interdisciplinary course that provides for students wanting to study only one science course in the senior secondary years. It could have an emphasis on contemporary science and technological applications. The integrating themes of science as a human endeavour, scientific inquiry and contemporary science should be embedded into all of these courses where realistically possible.

57 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.

PEDAGOGY AND ASSESSMENT

Pedagogy

58 Important for the design of a world-class curriculum is the recognition of the dynamic alignment that exists between curriculum, pedagogy and assessment. While this document focuses on the proposed content of a national science curriculum it is important to consider each of these elements to ensure the development of a flexible and rigorous curriculum that encourages high expectations with meaningful and rewarding opportunities catering for the diverse needs of learners.

59 To achieve the stated aims of the national science curriculum it is proposed that there needs to be less emphasis on a transmission model of pedagogy and more emphasis on a model of student engagement and inquiry. The driving force of the transmission model is teacher explanation whereas the learning engine for inquiry is based on teacher questions and discussion. Teacher explanation is still important but it should be seen as one skill in a broad repertoire of teaching skills.

60 A more balanced and engaging approach to teaching science will typically involve context, exploration, explanation and application. Wherever appropriate, students should be actively involved in the science topic or concepts to be taught. This requires a context or point of relevance by which students can make sense of the ideas to be learnt. The context may vary depending on the students, school or location. Having set the scene, the teacher provides science activities by which students can explore the ideas, using language the students are familiar with. Using this exploration and experience as a basis, the teacher introduces the science concepts and science terms in a way that has meaning to students. With these explanations and science language, the teacher then provides activities through which students can apply the science concepts to new situations.

61 The focus on scientific capabilities presented in this paper assumes an approach to teaching and learning that will develop and reinforce these capabilities.

Assessment

62 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 there must be a clear and realistic picture of how the curriculum will be assessed.

63 Within its many purposes, assessment should serve the purpose of learning. Assessment should encourage longer-term understanding and enable the provision of detailed diagnostic information to support student learning. It should show what students know, understand and can demonstrate. It should also show what they need to do to improve.

64 In particular, some of the important science learning aspects concerning attitudes and skills outlined in this paper, as part of the science capabilities, will require a variety of assessment approaches.

CONCLUSION

65 The national science curriculum will provide the basis for learning science that will engage students in meaningful ways and, with the support of teachers, help them to develop their science understanding so that they can function effectively in a scientifically and technologically advanced society. The desired result is that students will be interested in and understand the world about them, be able to communicate scientifically, be sceptical and questioning of the claims of others, and be able to identify and investigate questions and draw evidence-based conclusions.

66 By undertaking this curriculum students will be able to choose whether they wish to pursue a career as a scientist or be employed in science-related industries or services or in some other field. Regardless of their choice of career path, students are expected to complete their schooling as scientifically capable persons who can make informed decisions about the environment and their own health and wellbeing.

ACKNOWLEDGMENTS

This paper draws 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. 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 titled 'Boosting Science Learning: What will it take?' held in Canberra in 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 on improving school science learning.

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APPENDIX 1

The national curriculum: principles and specifications for development

The National Curriculum Board's work will be guided by the following principles and specifications for development:

a) The curriculum should make clear to teachers what has to be taught and to students what they should learn and what achievement standards are expected of them. This means that curriculum documents will be explicit about knowledge, understanding and skills and will provide a clear foundation for the development of a teaching program.

b) The curriculum should be based on the assumptions that all students can learn and that every child matters. It should set high standards and ensure that they apply to all young Australians while acknowledging the markedly different rates at which students develop.

c) The curriculum should connect with and build on the early years learning framework being developed for the pre-K phase.

d) The curriculum should build firm foundational skills and a basis for the development of expertise by those who move to specialised advanced studies in academic disciplines, professions and technical trades. It should anticipate and provide for an increase in the proportion of students who remain in education and training to complete Year 12 or equivalent vocational education and training and the proportion who continue to further study.

e) The curriculum should provide students with an understanding of the past that has shaped the society and culture in which they are growing and developing, and with knowledge, understandings and skills that will help them in their future lives.

f) The curriculum should be feasible, taking account of the time and resources available to teachers and students and the time it takes to learn complex concepts and ideas. In particular, the curriculum documents should take account of the fact that many primary teachers are responsible for several learning areas and should limit the volume of material which they must read in order to develop teaching programs.

g) The primary audience for national curriculum documents should be classroom teachers. Documents should be concise and expressed in plain language which, nevertheless, preserves a complexity in ideas appropriate for professional practitioners. Documents should be recognisably similar across learning areas in language, structure and length.

h) Time demands on students must leave room for learning areas that will not be part of the national curriculum.

i) The curriculum should allow jurisdictions, systems and schools to implement it in a way that values teachers' professional knowledge and reflects local contexts.

j) The curriculum should be established on a strong evidence base on learning, pedagogy and what works in professional practice and should encourage teachers to experiment systematically with and evaluate their practices.

(National Curriculum Board 2008:4)

Science Advisory Group

The advice in this paper was provided by an advisory group led by Professor Denis Goodrum.

Professor Denis Goodrum, Professor of Science Education, Faculty of Education, University of Canberra, Australian Capital Territory

Professor Leonie Rennie, Dean, Graduate Studies Organisation, Science and Mathematics Education Centre, Curtin University

Professor Russell Tytler, Professor of Science, Mathematics and Technology Education, Deakin University

Shelley Peers, Australian Academy of Science — Education and Public Awareness Manager (including role as Managing Director of the 'Primary Connections Project' from April 2005)

Glen Sawle, Senior Science Curriculum Officer, Dept. of Education and Training, New South Wales

Nicolette Burraston, High School Teacher, Cowra High School, New South Wales

Debbie Smith, Head of Science, Centenary State High School, Queensland, Treasurer of the Australian Science Teachers Association

Peter Russo, CEO Australian Science Teachers Association

Professor Peter Fensham, Monash University, Emeritus Professor; Queensland University of Technology, Adjunct Professor

Professor Martin Westwell, Director, Flinders Centre for Science Education in the 21st Century, Flinders University

Dr Jim Peacock, Research Fellow of CSIRO Plant Industry, former Australian Chief Scientist

Special acknowledgment

A special acknowledgment goes to Professor Leonie Rennie for providing extensive comment and input during development of this paper.

Appendix 3: Feedback questions

To provide us with feedback on this paper, please respond to the questions below. Your replies are a rich source of information and are of great value to us.

<table>
<tr><td colspan="4">Name:</td></tr>
<tr><td colspan="4">Organisation (if applicable):</td></tr>
<tr><td colspan="4">Postal address:</td></tr>
<tr><td colspan="4">Please nominate your area/areas of interest?</td></tr>
<tr><td>☐ English</td><td>☐ Mathematics</td><td>☐ Science</td><td>☐ History</td></tr>
<tr><td colspan="4">Please choose:</td></tr>
<tr><td>☐ Academic</td><td>☐ Business or Industry Professional</td><td colspan="2" rowspan="4">Education professional
☐ Chief Executive Officer
☐ Curriculum Director
☐ Curriculum Manager
☐ Departmental/Sector Representative
☐ Principal
☐ Professional Organisation Representative
☐ School Administrator
☐ Teacher
☐ Teacher’s Aide</td></tr>
<tr><td>☐ Community Member</td><td>☐ Journalist</td></tr>
<tr><td>☐ Parent</td><td>☐ Student</td></tr>
<tr><td>☐ Union Representative</td><td>☐ Youth Leader</td></tr>
</table>

Introduction

1. Please comment on the Introduction.

Aims

2. To what extent do you agree with the aims of the proposed national science curriculum?

(Click here to select your choice)

2. Please comment on the aims of the proposed national science curriculum.

Terms used in this paper

4. To what extent do you agree with the definitions and applications of the terms used in this paper?
(Click here to select your choice)

5. Please comment.

Considerations

6. Comment on the considerations that need to be taken into account when developing national science curriculum. Are there other considerations not canvassed in the paper?

Structure of the curriculum

7. The paper outlines three elements: *Science understanding, Science inquiry skills* and *Science as a human endeavour.* To what extent do you agree with these elements as the basis for the national science curriculum?
(Click here to select your choice)

8. Please comment.

9. The proposed structure identifies the curriculum focus, sources of science understanding and the relevant big ideas of science for each stage of schooling. To what extent do you agree with using these headings as organisers for the curriculum?
(Click here to select your choice)

10. Please comment.

11. To what extent do you agree with this approach to organising the science content for Stage 1?
(Click here to select your choice)

12. Please comment.

13. To what extent do you agree with this approach to organising the science content for Stage 2?
(Click here to select your choice)

14. Please comment.

15. To what extent do you agree with this approach to organising the science content for Stage 3?

(Click here to select your choice)

16. Please comment.

17. How many science courses should be included in the national science curriculum in the senior secondary years of schooling?

18. Please comment.

Question 19: This section outlines approaches to pedagogy as they apply to the content of a national science curriculum. To what extent do you agree?

(Click here to select your choice)

Question 20: Please comment:

Question 21: This section outlines approaches to assessment as they apply to the content of a national science curriculum. To what extent do you agree?

(Click here to select your choice)

Question 22: Please comment:

23. Do you have any other comments to make on the paper?

Send feedback

Preferred method	***Alternative methods***
Please complete this form and email as an attachment to: *feedback@ncb.org.au*	*Post to:* National Curriculum Board PO Box 177 Carlton South VIC 3053 *Fax to:* (03) 8330 9401