Chapter 1

Making sense of primary science

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Learning objectives

After reading this chapter, you should be able to:

• Clarify the purpose and intention of the primary science curriculum and of science teaching;

• Outline existing primary teacher expertise in teaching primary science; and

• Identify the conditions which enhance effective science learning in primary school education.
At a recent professional learning program, the question, ‘What is science?’ was posed to a group of primary teachers. The teachers asked for clarification: ‘science’ as in ‘school science’ or ‘science’ in the ‘real world’? The facilitator’s response was to ask: ‘Is there a difference, and should there be a difference?’ This conversation is interesting because it captures some important considerations for understanding science education in primary school settings. Firstly, a range of opinions, assumptions and understandings may shape teachers’ thinking about science, and these have potential implications for student learning. Secondly, school science often does not mirror how we see, experience or use science in the world around us.

It is often said the only place you see Bunsen burners is in schools. The only place you write up a prac (sic) report is in schools. The only place you wear white lab coats, memorise the periodic table, mix bi-carb and vinegar, or make a volcano, is in schools; just in case you ever need to – which most of us don’t. Somehow we’ve remained stuck representing to students an outmoded, irrelevant, and possibly inaccurate perspective of science (Lindsay, 2011, p.3).

These considerations resonate with primary teachers who openly express specific concerns about their science teaching – in particular, their sense of having an inadequate personal knowledge of science content and the influence of this when they teach science. This tension unnecessarily suggests that because primary teachers are *generalist teachers*, they may be less effective science educators. This is far from the truth, because as generalist teachers they bring a range of pedagogical strengths to science education which are often not recognised. They understand how to successfully contextualise the nature of *science as a human endeavour* by creating classroom conditions which value student-centred learning, nurture curiosity and creativity, and support the *social construction of knowledge*. Many have demonstrated a willingness to understand more about *scientific literacy*, utilise authentic learning...
experiences, develop students’ critical thinking and communication skills, encourage productive and independent student learning behaviours, and empower students to take action as citizen scientists.

This chapter attempts to explicitly outline and explore some of these teaching strengths in more detail. This is important because, unfortunately, the inadequacy of teacher content knowledge has dominated debate around the quality of primary science education. While teacher content knowledge remains an essential element of effective pedagogy which should not be underestimated, continually framing primary science teaching around this deficit model has undervalued and largely ignored the range of pedagogical strengths that primary teachers bring to science education. It is time to shift this debate and interrupt the relentless fixation on the one area of primary teachers’ practice that holds their deepest feelings of personal inadequacy.

A more productive approach may be to identify the unique ways in which primary teachers develop many other undervalued, yet essential, conditions for effective science education. Teachers must feel comfortable enough to share their professional knowledge, their practice and their expertise, without fear of judgment. By doing so it is hoped that teachers themselves can begin to notice, articulate and value their professional knowledge, and be better motivated to enhance their science pedagogical content knowledge by finding strategic ways to access and make sense of conceptual understandings.

Valuing primary teachers’ pedagogical expertise

Until recent times, the view of science as a form of public knowledge or accepted thinking has framed the purpose of science education; that is, teaching science has really been about placing scientists’ conceptions in students’ minds (Fensham, 1988). In this context, science has often been represented through school curriculum and science teaching as a rigid body of absolute, unchanging truths, consisting of isolated facts devoid of human imagination and logical reasoning, disconnected from society and culture, and often having no real application to everyday life. This representation of science has created some huge challenges for primary teachers, and as a consequence science teaching in many primary schools has either been neglected or reduced to a collection of activities and experiments to address curriculum (Angus, Olney & Ainley, 2007; Goodrum, Hackling & Rennie, 2001).

Educational discourse around the cause of these apparent deficiencies in primary science education has focused on the connection between primary teachers’ limited knowledge of science content and their reluctance to teach science. This lack of personal background knowledge appears to be influenced by primary teachers’
tendency to focus on non-science studies in their own schooling and teacher preparation, which appears to diminish their confidence to teach sciences (Appleton, 1995; Skamp, 1989). Appleton (2003) states that a recurring theme in much of the literature about primary science education has been the degree of preparedness and apparent reluctance of many teachers to teach science (e.g., Appleton, 1977, 1995; Department of Employment, Education, and Training (DEET), 1989; Harlen, 1997). While lack of content knowledge may be one explanation for primary teachers’ reluctance and disaffection for science teaching, another major consideration may be the constrained teaching approaches this traditional focus has imposed on school science.

In most other areas of the curriculum, primary teachers attempt to create meaningful connections and relevant contexts for learning. They promote and value diversity of views among their students, and frequently explore and utilise social issues and real-world situations to position and explore these views. These aspects of practice matter to primary teachers because they create the conditions which engage students and develop meaningful learning. Yet such approaches are not always possible when school science is framed as a static body of knowledge and facts. This immediately limits the types of learning experiences teachers feel they are able to provide for their students, and disconnects science from their students’ real-life experiences.

To develop a more active involvement in science education, primary teachers may need to see more relevance in science education for their students. Smith, Loughran, Berry and Dimitrakopoulos (2011) identified that amongst a group of primary teachers working to promote scientific literacy as a learning outcome for their students, there was a shared belief that quality primary science teaching relied on pedagogy that essentially valued and worked at building a connectedness between students and their world. This belief guided the practice of these teachers and required them to reconnect scientific knowledge to its dependency on human activity, and to explore science as a way of thinking and acting. As one of these teachers explains in the following quote, such human activity created a sense of ownership and a purpose for student learning.

Scientific knowledge is great but unless our students are able to identify its existence in the world around them, analyse it, critique it, challenge it and change it then what impact can they have on it? The understanding of scientific literacy held by the students of 6W and myself is similar in one element – science is continually evolving and improving (A. Walsh, 2011, p. 92).

Experienced primary teachers have a high level of pedagogical expertise and knowledge about effective learning and teaching. This knowledge underpins their practice, and this thinking needs to be recognised and attended to as an important consideration in primary science teaching, just as in any area of the curriculum.
Reframing the purpose and intention of primary school science
The Australian Curriculum and New Zealand Curriculum documents (Australian Curriculum, Assessment and Reporting Authority (ACARA), 2012; Ministry of Education (MoE), 2007) outline a vision for student learning in science from the beginning of the formal schooling years (known as Foundation in Australia and Year 1 in New Zealand) to Year 10 in Australia and Year 13 in New Zealand. Both documents explicitly outline the development of science content knowledge (known in Australia as Science Understanding, and in New Zealand grouped into the following four conceptual areas: Living World, Physical World, Material World and Planet Earth and Beyond) along with scientific procedural skills (known as Science Inquiry Skills in Australia and Investigating in Science in New Zealand). Interestingly, both documents have also attempted to move science beyond a set of conceptual understandings and procedures to also value an emphasis on science as human activity involving thinking and action. In the Australian Curriculum, the strand Science as Human Endeavour has been developed to attend to this important aspect of science learning, while in the New Zealand Curriculum, the achievement aims of Communicating in Science and Participating and Contributing have been added. These curriculum developments give primary teachers permission to move science learning and teaching beyond the more traditional notions.

Science as a human endeavour
The focus on science as a human endeavour in the Australian and New Zealand science curricula (ACARA, 2012; MoE, 2007) acknowledges that it is important to attend to the complex behaviours and values that enable scientists to know what they claim to know. This construct refers to the very nature of the processes involved in the social construction of knowledge. Science as a way of knowing (Lederman, 1992; Lederman 1996) and thinking about the world is fundamentally underpinned by characteristics including observation, questioning, empirical data, inference, justification, communication, peer-review for social interrogation, critical analysis and ultimately validation. These aspects of scientific activity are all interrelated to culture, reliant on empirical observation, subject to change, and are all interdependent (Schwartz, Lederman & Crawford, 2004). Student learning behaviours that exemplify these characteristics become important representations of science as a human endeavour in classroom learning.

In general, primary teachers’ pedagogy aims to assist student learning by creating opportunities which:
• Sensitise students to the physical and social world in which they exist;
• Nurture student curiosity;
• Empower students to develop and trial formal and informal problem-solving strategies;
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- Encourage students to construct informed viewpoints and evidence-based decisions;
- Encourage students to develop effective communication and interpersonal learning skills;
- Require students to practise critical thinking skills; and
- Allow students to link learning with their personal world and their wider sense of community.

With these aims in mind, the primary classroom becomes a powerful context for exploring science as a human endeavour, because teachers are actively creating the conditions where school science becomes a working example of the interrelatedness of humanity, learning, society and science. Yet most primary teachers would fail to recognise how this contributes to science education.

If primary teachers are supported to think about science in ways which value the characteristics of science as a human endeavour, they can begin to recognise that their existing teaching attends to the social, intellectual and practical dynamics that make science a unique way of knowing. Primary school teachers bring personal values about quality learning to science teaching, and they use these values to find the most effective ways to attend to student learning needs and curriculum requirements. The primary classroom provides opportunities to characterise and live science as a way of knowing and acting. For primary teachers this may begin to clarify a richer pedagogical purpose for science education.

Developing scientific literacy

Scientific literacy is being increasingly viewed as the primary goal of school science, with agreement that the purpose of science education should be focused towards developing scientifically literate citizens (Goodrum et al., 2001; Millar, 2007). The term calls into question the traditional structures and intention of science education. Roberts (2007) referred to these inherent tensions when he described two differing positions for curriculum design – two extreme positions on a continuum of understanding. Vision 1 focuses on the processes and products of science itself (i.e., decontextualised science subject-matter). Vision 2 is student-centered and examines the scientific components of situations that students are likely to be faced with in their daily lives. This second vision suggests literacies that connect with context-driven, science-related situations, and embodies a view that curriculum should be designed to prepare students for life and work as citizens. The science curricula of Australia and New Zealand incorporate notions of scientific literacy, but the skills and values that may characterise scientifically literate students are not overtly stated.

If indeed the aim of science education is to develop scientific literacy in terms of enhancing students’ capacities to function as responsible, savvy participants in
their everyday lives (Aikenhead, 2007), then there is a need to understand what characterises a scientifically literate person. As part of the call for a greater focus on developing scientific literacy in Australian schools, the report *The Status and Quality of Teaching and Learning of Science in Australian Schools* (Goodrum et al., 2001) identified a number of attributes of a scientifically literate person. These were:

- Interested in and understand the world about them;
- Able to identify and investigate questions and draw evidence-based conclusions;
- Able to engage in discussions of and about science matters;
- Skeptical and questioning of claims made by others; and
- Able to make informed decisions about the environment and their own health and wellbeing (Hackling, Goodrum & Rennie, 2001, p. 7).

Scientifically literate citizens are therefore characterised as being curious, questioning, and able to engage with science in ways that allow them to critically interrogate and make sense of information. Rather than being discipline-based, as in Roberts’ Vision 1, this perspective of scientific literacy focuses on the development of a more generic set of skills that would assist individuals in dealing with scientific issues and phenomena that impact on daily life. In broad agreement, Norris and Phillips’ (2003) examination of the literature produced a list of factors characterising scientific literacy which included: the desire to be an independent, lifelong learner of science; a willingness to engage with scientific ideas; and the ability to interpret and construct science texts. Their review argues that while scientific literacy should focus on students’ orientations to science, it should also encompass their abilities regarding the understanding and application of scientific ideas.

The concept of scientific literacy reframes the process of science learning as being active and adaptive rather than simply leading to resolved conceptual end-points. Aikenhead (2006) refers to a humanistic perspective of school science that may complement the existing pedagogical strengths of primary teachers. This perspective shifts school science from the acquisition of conceptual knowledge to the fostering of a positive view of science that encourages students to engage with scientific ideas in ways that will assist them in their learning journey.

**Changing the conversation:**
**Acknowledging primary teacher expertise in teaching primary science**

The world is ever changing; information is relatively easy to access both at school and at home with a growing range of available multimedia tools. News about local and global events is constant, immediate and often overwhelming. As an educator I need to equip my students for life in this world and I believe that enabling students to become scientifically literate is the key to education in this 21st century. So
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what does this mean and what does this look like in the classroom? I believe that my teaching must help students to become critical, discerning thinkers who are able to listen, consider, question and interrogate what they read and what they hear. They need to be able to think and adapt to various environments and make decisions about a whole range of changing issues (France, 2011, p.101).

This quote from a primary teacher captures the professional thinking that underpinned her practice as she attempted to unravel some of the pedagogical complexities associated with promoting scientific literacy as an outcome for her students. Now, with the support of current science curriculum documents, primary teachers can confidently move their students beyond simply knowing science to knowing about science in ways that are relevant to their lives and the future choices that they may need to make. It is time to acknowledge that many primary teachers, such as the teacher quoted, are already using effective professional practices that will support these new perspectives for science learning and teaching. The following six sections explore some of these practices and attempt to highlight the significant contributions such practices can make to primary science education.

Conditions that effectively support the social construction of knowledge

As part of a school-based study (Smith et al, 2011), a group of primary teachers explored the meaning of scientific literacy. The teachers in the study found that teaching for scientific literacy was far more than linking learning to everyday events or using contemporary technology to simulate and explore science concepts. Teaching science became a holistic approach to teaching: developing the whole person; nurturing in each student a noticing of life and natural phenomena; and creating opportunities for students to construct meaning. Science learning was essentially about curiosity, a willingness to question, and an intrinsic need to seek understanding (Smith, 2011). For these teachers it became extremely important to create opportunities in the classroom for interpersonal and collaborative learning because it was through social interaction that children’s ideas were ultimately given meaning. This is evident in the following quote.

One of the great influences of working in teams, and effective teams at that, on scientific literacy is that it allows for good discussion. The ability to have robust discussion over a subject that presents a multitude of perspectives is fantastic. It ensures that all sides of an argument can be covered and that questions are asked that you may not think of when looking from only one individual’s perspective (A. Walsh, 2011, p. 86).

These professional insights recognise that the learner must construct knowledge. Encouraging students to communicate, reflect on and make sense of their own thinking becomes essential for developing meaningful and useful knowledge. One of the teachers, Tracy, developed the figure below to further explain her thinking about the important experiences which contributed to the social construction of knowledge.
As is evident from figure 1.1, primary teachers already value and use strategies which promote the social construction of knowledge in their classrooms. Their pedagogy enables students to work together as a learning community to construct, articulate and share meaning. The culture and infrastructures inherent in primary education make these conditions achievable for science learning. Primary teachers work intensively with the same group of students across a twelve-month time frame, so they have the opportunity to specifically identify their students’ learning needs and interests and build effective relationships. Primary teachers recognise the importance of providing students with opportunities to articulate their ideas and share their thinking. They create opportunities for students to interact and work together, and encourage them to draw on thinking and skills from a range of curriculum areas to process and construct new ideas and understandings. When science becomes about
thinking and action, the pedagogical focus is on meaningful and purposeful learning, and these existing conditions enhance the kind of learning outcomes in primary school science outlined in figure 1.1.

Nurturing curiosity and creativity
Common themes underpinning secondary student dissatisfaction are perceptions that school science is dull, teacher-driven and fact-orientated with little room for creativity, enjoyment and curiosity (Fensham, 2006 August; Schreiner & Sjøberg, 2004). It should be acknowledged, however, that these sentiments do not necessarily represent the perceptions that primary school students hold towards school science. In fact, many primary teachers create classroom conditions that actively foster these values.

While primary teachers typically and openly embrace the notion of creativity through the learning and teaching strategies and approaches they use, this does not automatically equate to this value being imparted or encouraged through the science learning area (Parliamentary Office of Science and Technology, 2003). However, in thinking and working scientifically, there is a need for students to engage with science in creative ways.

In acknowledging the tensions that primary school teachers face in relation to science education and the need to think differently about their practice, creativity – a useful component of their usual repertoire – may be a starting point for bringing about change. The vignette described below, drawn from the work of Fitzgerald (2010), captures a sequence that may be helpful in starting to think about what this reframing of science learning and teaching might look like. In this case, the primary school teacher encouraged her students to develop a creative representation of their science understandings. This task required them to think creatively to construct their science knowledge in a new way.

The three Year 7 girls giggled nervously as they stood at the front of their classroom. (Year 7 is the final year of primary school in the Australian state in which this research was conducted.) Their teacher, Deanne, shushed their classmates and reminded them that they were to use the rubrics in front of them to rate the girls’ performance. They were to consider areas such as use of science words, understanding of the science concepts and teamwork, and to score them on a scale of 0 (not shown) to 10 (excellent). The girls composed themselves and launched into their rap about matter. Their self-composed song included lyrics such as ‘liquid, solid and gas is anything with volume and mass’ and ‘you know solid, it don’t flow; you know liquid, it’s on the go; you know gas, it just don’t show’. This science rap song was one of several performed that morning, all of which covered the conceptual areas of matter, properties of materials or change. These performances signalled the culmination of their 10-lesson chemistry unit.