Chapter 2
Blurring the Boundary Between the Classroom and the Community: Challenges for Teachers' Professional Knowledge

Léonie J. Rennie

"Teachers, students, parents and Dr C. We hope you enjoy our performance. We would like to tell you why we wrote the Potato Rap. We were given this challenge by Dr C. to see if we could inform you that this is the International Year of the Potato. Why would anybody want to make an International Year of the Potato, after all, it's just a potato, right? But once we started to research potatoes, we found out some interesting facts…"
Soon the spokesperson for the Year 4 class introduced Dr C., the school's visiting scientist (a potato pathologist), to the school assembly, who explained,
"I work with a lot of sick potatoes, and just like a doctor, we have to find out which potatoes are sick, why they are sick, and see if we can find a cure. The work that we do as scientists helps you to have a constant supply of potatoes."
He thanked the class for their performance and some rap music began to throb.
"Hey!"
shouted 25 potatoes in unison—the entire class was on the stage, dressed in coloured tights stuffed with crumpled paper—brown potatoes, yellow potatoes, purple potatoes, white potatoes, pink potatoes.
"What do you know?
All the world eats"
and 25 potatoes threw their arms in the air, shouting
"Potatoes!"
The rap music continued:
"How do you know if a potato is sick?"
(A large brown potato at the front of the group collapsed dramatically, but gracefully, to the stage.)
"Find a 'tato pathologist really quick!"
(A white potato comes to the rescue.)
"They are like a doctor, calling around"
(The brown potato is rapidly cured.)
"They'll keep potatoes healthy and brown!
Potatoes!"
Caught up in the class's enthusiasm, the audience of delighted parents and other students at the assembly raised their hands and joined the shout before the next verse of the Potato Rap.

L. J. Rennie (✉)
Curtin University of Technology, Perth, WA, Australia

D. Corrigan et al. (eds.), *The Professional Knowledge Base of Science Teaching*,
DOI 10.1007/978-90-481-3927-9_2, © Springer Science+Business Media B.V. 2011

This story illustrates one outcome of the *Scientists in Schools* project in Australia, which aimed to establish sustained and ongoing partnerships between scientists and school communities.[1] Evaluation of the project demonstrated benefits to scientists, teachers and students (Rennie and Howitt 2009), not the least of which was renewed enjoyment of and enthusiasm for science amongst all participants. Further, there was a strong dose of professional learning and increased confidence for teachers, especially those in primary schools who professed to know "not much" about science. One of these teachers was Mrs R., whose strong pedagogical knowledge and creative enthusiasm enabled very positive outcomes from her Year 4 class's research on potatoes with their scientist, Dr C.

Scientists in Schools is a project that blurs the boundaries between schools and communities. Scientists and teachers work together, often on a regular basis, in ways that enable students to experience "real-world" science and teachers to stay in touch with contemporary science outside of school. Projects that promote science and scientists to schools and their communities can make a positive difference to students' engagement and interest in science education. This chapter is about the place and promise of programs, like *Scientists in Schools*, that blur the school–community boundary, and it begins with some background to describe that boundary in terms of the present state of science education in the Western world.

Background: The Quality of Science Education

Scientists in Schools was launched in July, 2007, the same month that the World Conference on Science and Technology Education was held in Perth, Western Australia. Building on a policy options paper he had drafted for the World Conference, Fensham (2008) identified 11 emerging issues for policy makers, noting that "the quality of school education in science and technology has never before been of such critical importance to governments" (p. 4). One of those issues is interest in and about science, and he recommended that personal and societal interest about science should be the reference point for curriculum decision-making.[2] Two other issues concerned the quality of learning and the need for an effective assessment system. Similarly, Osborne and Dillon's (2008) reflections on science education in Europe identified a lack of perceived relevance, a pedagogy that lacked variety, and an assessment system that encouraged rote, rather than mastery learning,

[1] The *Scientists in Schools* project is an initiative of the Australian Government's Department of Education, Employment, and Workplace Relations, and is managed by the Commonwealth Scientific and Industrial Research Organisation.

[2] The focus here is on Western countries (from where national reports are more readily obtained), but projects like the Relevance of Science Education (ROSE) indicate that in terms of interest in, and commitment to, science, the Western countries are those where the situation is most dire (Schreiner and Sjøberg 2007). In developing countries, a science career is much more likely to be a passport to well-paid employment and so the value of science education remains high.

amongst the reasons for students' lack of engagement in science. The European Commission's High Level Group on Science Education called for action to increase students' interest in science through a renewed, inquiry-based pedagogy (European Commission 2007). The Group also argued for increased opportunities for cooperation between the formal and informal arenas, an argument endorsed and extended by Stocklmayer et al. (2010).

The search for a science education that students find engaging has turned attention towards a curriculum that places more focus on the world outside of school, and less on the discipline-specific kind of curriculum traditionally offered to our students. This refocus is based on the reasonable view that if students are to operate as informed citizens in a world that is becoming increasingly global, then the science curriculum they experience at school must be sufficiently meaningful and relevant for them to perceive links with what they experience outside the school doors. Unfortunately, creating and delivering a curriculum that has such a focus turns out to be a very large challenge to how science education usually works in schools, as Osborne et al. (2002) discovered in their evaluation of the pilot phase of the *AS Science for Public Understanding* course. Although students enjoyed it, Osborne et al. found that achievement of its broader aims was limited by the difficulties teachers experienced in changing the culture of their pedagogical practice. "Changing the curriculum is one thing", Osborne (2007) pointed out, "Asking teachers to change their pedagogy to meet the demands of such a curriculum is another" (p. 181).

In this chapter, some of the problems inherent in refocusing the science curriculum to include more links with the world outside of school are identified, and the conflicts that arise for teachers are explored. In particular, the underlying tensions between teaching for disciplinary knowledge and teaching for understanding of real-world, interdisciplinary problems are examined and an argument is made for a more balanced view of science curriculum that can serve the need for students to become scientifically literate citizens. Such a curriculum creates particular challenges for teachers, and the professional knowledge required and how it may be developed, are also explored.

Science Curriculum and Scientific Literacy

Increasingly, school science curricula have endorsed scientific literacy as a key outcome. The *National Science Education Standards* (National Science Council 1996) and *Twenty-First Century Science* (http://www.21stcenturyscience.org) are examples of curricula that state this emphasis clearly. However, scientific literacy is a contested concept, variously defined in various contexts. Further, how scientific literacy is envisaged in the documents describing the intended curriculum, can be quite different to how scientific literacy is portrayed in the curriculum implemented in the classroom.

In his analysis of scientific literacy/science literacy, Roberts (2007) sorted out some of the confusion in its meaning by referring back to

> a continuing political and intellectual tension that has always been inherent in science education itself. …two legitimate but potentially conflicting curriculum sources: science subject matter itself and situations in which science can legitimately be seen to play a role in other human affairs. (p. 729)

Roberts (2007) proposed, as a heuristic device, two visions of scientific literacy that reflect the extremes of these two sources: "Vision I gives meaning to SL [scientific literacy/science literacy] by looking inward to the canon of orthodox natural science, that is the products and processes of science itself" (p. 730), whilst "Vision II derives its meaning from the character of situations with a scientific component, situations that students are likely to encounter as citizens" (p. 730). Roberts gave examples of curricula and the Visions from which they were derived. Most traditional, discipline-based curricula draw from Vision I but *Twenty-First Century Science* draws primarily from Vision II.

Gardner (1975) illustrated how the curricula developed for science education during the 1950s and 1960s reflected the views of influential educationists of the time: "school subjects should serve as faithful and valid introductions to the academic disciplines whose names they bear" (pp. 1–2). These curricula exemplify a Vision I perspective of scientific literacy, focused on the key concepts of science independent of the real-world context in which those concepts might be applied. Most current curricula are traditional in the sense that they focus on the disciplinary knowledge of science, but some look beyond this, to the science-related issues students experience in their world.

Recently, Duschl (2008) documented "an important change in focus for science education, one that embraces a shift from teaching about *what* to teaching about *how* and *why*" (p. 270, original emphasis). Duschl noted "a connectedness in the practices of science that [is] not typically found in school classroom environments" (p. 272), and "the blurring of the boundaries between science and technology, and between different branches of the sciences themselves" (p. 274). The curricula that provide a connectedness between the discipline of science and the science students experience outside of the classroom draw from Roberts' Vision II. However, by making connections with science outside of school, these Vision II curricula do not ignore the discipline knowledge of science. The Visions are not mutually exclusive, as Roberts pointed out: "Vision II subsumes Vision I but the converse is not necessarily so" (p. 768).

Science in Everyday Situations

Aikenhead (2006) comprehensively reviewed research on the outcomes of traditional science curriculum and drew a conclusion that captured the central aspect of the boundary between science in school and science in the community. He stated that "research has produced one clear and consistent finding: *Most often canonical science content is not directly useable in science-related everyday situations*" (p. 29, original emphasis). Why is this so?

There are several reasons why it is difficult for students to use the canonical science content of traditional curriculum to help them make sense of the science in their everyday lives. Three of them are explored here. The first is that the science that happens outside of school differs from the science that is learned in school. This occurs because the science concepts learned in school are idealised and simplified, stripped of all the associated and confounding variables that operate in the world outside of the textbook. For example, Newtonian physics and its associated laws, such as F=ma, are useful approximations but cannot easily be applied outside of textbook physics problems. The process of simplification designed to enable students to "understand" the concepts, unfortunately also works as a barrier to using those concepts in the real world. Because there are so many uncontrollable variables, it is difficult to tease out how the school science concepts can have practical relevance in real-world situations. Even when using them well, abstract explanations and imperfect predictions are usually the best outcome. Further, often the concepts needed to understand science-related issues derive not only from science, but from other disciplines, such as mathematics and geography. Science issues in the real world, such as climate change, genetic modification and dealing with epidemics, are interdisciplinary.

A second and related reason is that the significant science-related issues in our daily lives are often complex and not completely understood. As Ryder (2001) found in his analysis of science understanding for functional scientific literacy, "the science knowledge featuring in everyday contexts is characterised by uncertainty and dispute amongst scientists" (p. 37). Arguments about global warming, greenhouse gases and carbon emissions are consistently in the news and provide ready examples of disputes and disagreements amongst people with different interpretations of similar but incomplete scientific evidence. These disagreements illustrate a third reason for difficulty in using disciplinary science to understand scientific issues. Almost always, there are competing social, cultural, economic and political values that provide conflicting interpretations of how to use science knowledge to take actions for the benefit of society (Corrigan et al. 2007). Further, conflicting interpretations and incomplete knowledge mean that making decisions is a risky business. Learning to cope with uncertainty and risk is an important part of becoming scientifically literate in the Vision II sense, but it has rarely featured in science curricula, except for those based on Science, Technology, Society and Environment.

Thus we see that the disciplinary science that students experience in the classroom is not immediately discernible in the issues and problems in which it resides outside the classroom, because it is melded immutably with knowledge and understanding in a range of other subjects, including mathematics, geography and economics, and also is imbued with social, cultural and political values. In short, science in the world is interdisciplinary and value-laden. Major problems facing our increasingly global world need to be tackled by interdisciplinary teams. How can our students be prepared to face this interdisciplinary world? What do they need to know?

Knowledge and the Science Curriculum

In terms of the teaching and communication of science, Duschl (2008) asked, “What is most worth knowing? Is it what we know? Or is it how we know and why we believe in it even in the face of plausible competing alternatives?” (p. 278). Vision I and Vision II offer very different views about the purposes of knowledge and education. This is not surprising. In Vision I, knowledge is treated as separate from experience and separate from its political and economic uses. Disciplinary science knowledge is valued for itself. In Vision II, the focus is on learning and knowing, rather than on knowledge. Knowledge is valued because it can be used to make sense of experience. The pedagogical approaches are more concerned about why and how to teach science than about what to teach (Duschl 2008).

What is significant and what makes the contrast between Vision I and Vision II important for this chapter, is that schooling itself evidences a mix of both perspectives. Schools are social institutions and, historically, have a major role in knowledge transmission. Traditionally, the nature of science knowledge to be transmitted is more like the canonical concepts described by Aikenhead (2006). But increasingly, schools are expected to ready their students for life in the outside world, much of which does not require an extensive disciplinary knowledge of science. These are different roles for the school curriculum, reminiscent of Fensham’s (1985) point that the science curriculum has traditionally catered for the minority of students who wish to pursue further studies of science, and served less well the large majority who simply need enough science for citizenship. These two roles are conflicting rather than complementary, and for the most part, the conflict remains unresolved (Fensham 2008). Consequently, there will continue to be, at least for the time being, conflict between discipline-based curricula that provide orthodox, canonical science knowledge and integrated, interdisciplinary curricula that allow more flexibility in catering to students’ needs and the interests of the local school communities. Teachers are in the middle of this conflict.

The heart of this conflict is that schooling, particularly secondary schooling, is not shaped to reflect the interdisciplinarity of real-world issues. Instead, school curricula are usually arranged in disciplinary areas. Most curricula have a section identified as science, even though, as Jenkins (2007) pointed out, school science is a term that covers a variety of sciences with major conceptual and philosophical differences. Further, Fensham (2009) noted that the Anglo-American tradition of teaching discrete subjects in a vertical fashion (that is, the content each year builds on the previous) promotes the inward-looking Vision I of scientific literacy. However, students arrive at school each day informed by their experiences in the community which are more closely related to the outward-looking Vision II, but generally are expected to set aside knowledge from those experiences and, while at school, work with school-based disciplinary science knowledge and understandings that often seem quite narrow and disparate to their own experience. As a result we see the creation of a boundary between the disciplinary science knowledge needed in school and the functional science knowledge used in the community.

Can this boundary be blurred? Teaching a science curriculum that includes interaction with significant science-related issues beyond the classroom, demands that teachers work in interdisciplinary ways and integrate at least some parts of the curriculum. However, curriculum integration is neither well-understood nor well-accepted in science education. Venville and her colleagues (Venville et al. in press; Venville et al. 2002) explored the reasons for this. They found problems of definition, disagreement about the reasons for integration, difficulties for teachers implementing integrated curricula and arguments about the quality of learning that resulted.

Drawing on the theoretical perspectives of Bernstein (1971), Venville et al. (2002) drew attention to the challenge posed by curriculum integration to the status and power of academic, disciplinary knowledge, arguing that integration was at odds with the traditional hierarchies, customs and culture of schooling, which are closely tied to disciplinary-based learning and its assessment. In contrast, functional knowledge from an integrated curriculum was perceived to be more "everyday" and less academic. It was perceived to be of lower status and hence as less worthwhile. In synthesising their research, Venville et al. found evidence that the status assigned to disciplinary knowledge (upon which the important tertiary entrance examinations were based) was a persuasive deterrent to the introduction of integrated curriculum, particularly in secondary schools. As a way forward, Venville et al. (2002) suggested that rather than try to work with two apparently competing curriculum paradigms based on the nature of knowledge, a pragmatic approach to curriculum integration was needed, an approach that did not ignore the established disciplines, but positioned them within a more holistic view of knowledge. Such an approach to integrated curriculum would recognise students' knowledge as grounded in their experiences and contexts, and attempt to meet the needs of students, the school and the local community. In such an approach, "the disciplines are there, but they are omnipresent rather than omnipotent" (Venville et al. 2002, p. 70). Venville et al. suggested that school science should provide students with opportunities to develop a scientific literacy that includes knowledge of the disciplines but also knowledge of the more interdisciplinary science-related issues students meet outside of school, in other words, a balanced curriculum that blurs the boundaries between disciplinary science in school and functional science outside of school (see also Rennie et al. in press).

Scientific Literacy in a Balanced Curriculum

The balanced curriculum described by Venville et al. (2002) has a meaning for scientific literacy consistent with Roberts' (2007) Vision II. This is the kind of scientific literacy that Goodrum et al. (2001) proposed should be an outcome of science education. It is forward-looking and concerns citizenship. Scientifically literate people are considered to be those who are interested in and understand the world around them; engage in the discourses of and about science; are able to identify questions, collect data and draw evidence-based conclusions; are sceptical and questioning of claims made by others about scientific matters and make informed decisions about the environment and their own health and well-being (Goodrum et al. 2001). Such a definition requires that people have certain skills and abilities that enable them to cope in life both within and beyond the classroom, and some of those skills and abilities are identified in Table 2.1.

Inspection of Table 2.1 reveals that scientific knowledge is needed, but it must be the kind of science knowledge that can be applied in new situations. The relevant knowledge is more likely to be functional science knowledge. The listed skills also strongly support the development of social responsibility, providing a better chance of harmonising the conceptual, epistemic and social learning goals, as argued by Duschl (2008). If students are to develop the skills and abilities listed in Table 2.1, then their school science curriculum needs to include significant interaction with the world outside of school.

There is evidence that the kinds of skills and abilities listed in Table 2.1 can be developed when there are effective school–community links. Further, the learning outcomes for students can be both powerful and worthwhile. In recent case study research, Venville et al. (2008) discovered that the outcomes of an integrated curriculum in which middle-school students learned about the social, economic and scientific issues related to the health of a local lake were very powerful for the learners. Even though the content followed the interests of students and their teachers and was certainly context-dependent, the curriculum approach and the

Table 2.1 Components of scientific literacy and underlying skills and abilities. (Based on Rennie 2006)

Scientifically literate people	Underlying skills and abilities
Are interested in and understand the world around them	Select and apply relevant science knowledge and skills in daily life Seek information to explain new phenomena or solve problems
Engage in the discourses of and about science	Feel comfortable to listen to, and to read, write and talk about science in everyday situations
Are able to identify questions, investigate and draw evidence-based conclusions	Analyse issues and identify, obtain and use needed information Understand how scientists go about finding answers to questions Construct and defend an argument
Are sceptical and questioning of claims made by others about scientific matters	Assess the trustworthiness of claims and sources of evidence
Make informed decisions about the environment and their own health and well-being	Recognise and cope with risk and uncertainty in decision making Choose to act responsibly and ethically

learning it engendered "moved" students well beyond their local and particular knowledge. Venville et al. (in press) concluded that what the integrated curriculum taught and what was learned during the case study provided students with usable scientific knowledge as well as values in social and civic responsibility. They were able not only to think in ways appropriate to the problems and issues that faced their community, but were able to communicate and debate these issues, and suggest ways of addressing those problems and issues.

An important afterword to the case study which gave rise to these findings is that following the introduction of state-wide achievement testing in three subject areas, including science, the integrated approach to curriculum in the middle school was abandoned in favour of a return to Vision I disciplinary-based approaches with the aim of enhancing performance on the tests. This move effectively reinstated the boundary that had been blurred, even bridged, by the local lake contribution to the curriculum.

Changing Curriculum, Changing Teaching

The case study concluding the preceding discussion illustrates how the curriculum can be opened up to a stronger focus on science-related issues outside of the classroom and work, in an interdisciplinary way, to build upon the students' own interests and concerns. The afterword also illustrates just how difficult it is to maintain that focus. There is no doubt that the kinds of skills and abilities these students were developing were those described in Table 2.1, and that these students were given opportunities to become scientifically literate in the Vision II sense. The argument presented in this chapter is that more students can be given such opportunities if their experiences of science in school and science in the community are brought much closer together by using community resources to explore science-related issues that have local relevance, thus blurring the boundary between school and community. The kinds of resources available are almost boundless. Rennie (2006) drew attention to families and friends, institutions such as museums with an educational role, community and government organisations and the media, as readily available resources that provide almost continuous opportunities for students to learn about science, both explicitly or implicitly, outside of school.[3]

However, making effective use of community resources requires considerable investment of time and effort. Already we have seen that science in the real world is complicated: We cannot control all of the relevant variables; much current scientific knowledge is uncertain and incomplete, leading to disputes and disagreements; and there are competing values and risks in making decisions about how knowledge is best used. There are significant pedagogical consequences of this "messiness" of

[3] Further information is available in recent reviews of research in out-of-school learning (Bell et al. 2009; Rennie 2007; Stocklmayer et al. 2010) and guidance for teachers in using a range of community resources (Braund and Reiss 2004).

science in the real world. Teaching a science curriculum that involves interaction with controversial science-related issues, or with new kinds of resources from beyond the classroom, requires of teachers an enhanced knowledge base and a suite of pedagogical skills that differ from those needed to teach a discipline-based, concept-oriented curriculum. The remainder of the chapter will address these pedagogical consequences.

Teachers' Content Knowledge

Teaching is a busy, full-time activity, and while teachers work in their classrooms, knowledge in the world outside is changing. Many teachers will need to broaden their content knowledge to enable them to bring contemporary science into the classroom. Teachers who read about, and keep up-to-date with, knowledge advances in their particular field will be well-placed to do this, but teachers of general science, particularly teachers in primary schools who are responsible for teaching more subjects than science, face a daunting challenge. Assistance for these teachers may need to come from the community itself. When students explore issues using community resources, their teachers have opportunities to learn as well as their students. Consequently, it is important that teachers are willing to learn from community members and resources and even from the students themselves. Mrs R., whose class's performance opened this chapter, is a good example. In working with scientist Dr C., she learned a great deal about potatoes and the nematodes attacking them, and also about science and how it works in the community.

Teaching About Community Issues in the Classroom

Not only content knowledge, but pedagogical knowledge is required for teachers to incorporate authentic, community issues into the classroom, or to move students outside of the classroom to work with issues in the community. Of course, teachers have always had excursions or field trips, but most research indicates that they are not well-integrated into the school curriculum (Rennie 2007). Excursions are often expensive and there are organisational and administrative hurdles to overcome. Further, it takes considerable effort for teachers to ensure that they are used effectively. Not all teachers know how to do this, although research suggests that teachers with good content knowledge are better able to integrate learning from excursions and field trips into their curriculum (Rennie 2007).

A particularly difficult area for teachers is dealing with socio-scientific issues that are controversial (Ratcliffe and Grace 2003). Good content knowledge is required, but also an ability to feel comfortable in dealing with the risk, uncertainty and ambiguity that reside in such issues. In other words, teachers themselves need to be scientifically literate in the Vision II sense so that they can be comfortable dealing with the everyday situations that arise in the community, including through the media. Recent work in New Zealand by Saunders (2010) revealed that although most teachers believed that such issues had a place in the classroom, they also believed they needed help in teaching them. Saunders developed and field-tested a professional learning model for teachers, and those who used it not only found it rewarding but were astounded at the interest evidenced by students and the high quality of work they produced. However, not all teachers see their role in this way. Levinson and Turner (2001) reported that a majority of science teachers they interviewed in the United Kingdom believed that teaching science should be about facts and explanations, and that dealing with associated social and ethical issues were not part of their role. It would seem that the students of these teachers would be limited to developing a Vision I perspective of scientific literacy.

Helping students to learn about and use science in everyday contexts requires a high level of pedagogical content knowledge, because using knowledge in different contexts often requires considerable reworking of that knowledge so that it can be used in new situations. Some years ago, Layton et al. (1993) explored how four groups of adults in different situations sought out and made use of science knowledge they needed to deal with particular issues in their lives. These researchers found that in order to make use of that knowledge, people had to rework it into a form that made sense to them. Layton et al. described this process of deconstructing and then reconstructing the information, as transforming knowledge, or constructing "knowledge for practical action in [their] specific situations" (p. 128). Teachers need to keep in mind that this process is very difficult and therefore take opportunities to assist students to develop the skills of using knowledge in new situations.

In one of their studies, Venville et al. (2004) found that students attempting to use content knowledge from their school lessons in science, mathematics and technology to build a solar-powered boat, frequently abandoned that source of knowledge as unhelpful, and drew on other sources, such as observing other students, and asking friends and family members for advice. This is consistent with an important conclusion from Aikenhead's (2006) review, that "when the science curriculum does not include the difficult process of transforming abstract canonical content into content for taking action, canonical science remains unusable outside of school for most students" (p. 30).

Students are continuously learning from sources in the world outside of school, and often that learning is not consistent with the disciplinary science knowledge presented in the classroom. Teachers need to be aware of what students have already "learned" from these external sources, not only to harness its potential to engage students' interests, but also to help them rework that knowledge so that it is meaningful in school science. Assisting students to transform knowledge into a form that can be used where it is needed requires considerable pedagogical content knowledge to determine what students do understand (and misunderstand), what they need to understand and then how to shift their understanding. Years of conceptual change research indicates that this is not easy to do. Students will resist if they see no reason to change their commonsensical, quite workable, but possibly misconceived, ideas. Jenkins (2007) put it well: “for most everyday practical purposes, common-sense, as distinct from scientific, thinking, is perfectly adequate” (p. 277).

Teachers’ Professional Learning

The challenges to teachers’ professional knowledge are significant for most teachers. Changing the curriculum to bring the classroom and the community closer together, means changing their teaching, and teacher change is rarely easy. Understanding the kinds of things that need to change can be a first step in assisting teachers to progress. Bartholomew et al. (2004) provided a framework that can be useful in this regard. Their research with a group of teachers asked to use the “ideas-about-science” approach to teaching the nature of science resulted in the identification of five dimensions of practice that recognised the salient, but not independent, components of effective teaching. These dimensions were first, the degree of teachers’ confidence in their own knowledge and understanding of the nature of science; second, teachers’ conception of their own role, as either a dispenser of knowledge or a facilitator of learning; third, teachers’ use of discourse, as either closed and authoritative or open and dialogic; fourth, teachers’ conception of learning goals as either limited to knowledge gains or inclusive of the development of reasoning skills and fifth, the nature of classroom activities, in terms of whether they were contrived and inauthentic, or by students and therefore were authentic (Table 3, p. 664). Bartholomew et al. found that

> effective teaching of “ideas-about-science” requires establishing a context in which it is possible for students to engage in reflexive epistemic dialogue…. For many teachers, enculturated in the habitus of traditional science teaching, this would require a shift in conception of their own role from dispenser of knowledge to facilitator of learning; a change in their classroom discourse to one which is more open and dialogic; a shift in their conception of the learning goals of science lessons to one which incorporates the development of reasoning and an understanding of the epistemic basis of belief in science as well as the acquisition of knowledge; and the development of activities that link content and process in tasks whose point and value is transparent to their students. (p. 678)

The parallels between teaching ideas-about-science and teaching about science-related issues are instructive. Bartholomew et al. (2004) noted that, as teachers’ confidence grew and they became more used to dealing with the content, they began to offer a curriculum more like that described in the excerpt above. However, it was also clear that simply increasing teachers’ knowledge and understanding about what is intended to be taught is insufficient to result in a change in practice. There must be considerably more opportunities for professional learning and resources to support such a change. There also needs to be change in the way students’ learning is assessed. Many of the skills in the right hand column of Table 2.1 cannot easily be assessed using pencil and paper tests. Ways must be found to devise valid measures for the skills associated with a Vision II kind of scientific literacy. Abell’s (Chap. 12) discussion of what counts as evidence for learning is central to this issue. Teachers will not change their practice without a concomitant change in assessment that demonstrably values the intended outcomes of the new curriculum to be implemented.

Changing Teachers' Mindsets: Ways Forward

This chapter presents an argument that students' interest in science and their perceptions of its relevance for them can be enhanced by bringing science in the community into science in the classroom. Some of the difficulties of doing this have been explored. The messy nature of real-world science, compared with the comparatively clear-cut, traditional canonical science concepts that typically compose the school science curriculum, was explored as one barrier to be overcome. The difficulties teachers often face in dealing with interdisciplinary, integrated science of the kind that exists in the community were also explored, as was the need to overcome the perception, particularly in secondary schools, that this was a move towards lower status, less powerful science knowledge. Because of pressures of time and the need to cover the curriculum, teachers are frequently caught in the conflict between teaching disciplinary-based science (that is promoting a Vision I perspective) and broadening the science they teach to the kinds of experiences students have outside the classroom (that is, moving the science curriculum closer to Roberts' Vision II). Blurring the boundary between school and the community requires that teachers believe that this is worthwhile. Aikenhead, in the Introduction to his chapter in this volume, points out that many teachers have a belief system that "seems to revere the memorisation of facts, abstractions, and algorithms". Moving teachers to implement a curriculum more aligned with Vision II than Vision I requires changing this belief system, or mindset. This requires four key changes in teachers' beliefs.

First, teachers must believe that allowing students to experience functional science in the real world and see scientists in their work place is important, and that understanding and using science in context is important. It gives students opportunities to see the relevance of disciplinary science concepts and learn how to transfer knowledge from in class to science experiences out of class. Science, as it is practised, is messy, uncertain and conflicted with values in the real world. Students need opportunities to find this out and learn to deal with the inherent ambiguities and risks.

Second, teachers need to believe that some (but of course not all) science concepts enshrined in current traditional curricula can be sacrificed to provide time and space for students to learn by devising and investigating their own questions about matters that are important to them. Teachers need to believe that the outcomes of this approach are worthwhile.

Third, teachers need excellent pedagogical knowledge to help their students develop the abilities and the skills described in Table 2.1. Teachers need to be able to "let go" of, or at least slacken their grip on, the learning reins, and allow students to take more control of their own learning. Of course this requires that students have opportunities to learn how to ask "good" questions that can be investigated by collecting and evaluating data to arrive at answers supported by evidence. In this way, students learn the relevant concepts and how they can be used.

Fourth, teachers need to believe that there are many valid ways to assess learning. The summative written tests so firmly entrenched in current assessment methods have variable validity in measuring learning outcomes. There are other assessment methods that enable students to demonstrate what they know and can do. Taking the science-related situation, rather than the science concepts, as the starting point for assessment allows for more creative ways of gathering evidence about students' learning. This is an important message (Fensham 2008), and curricula will not change unless the prevailing assessment methods change.

Teachers Learning by Doing

In making the changes that lead to students developing the kind of scientific literacy advocated in this chapter, teachers need support because, at least initially, most of them will be swimming against a strong tide of traditional pedagogical practice. How can they gain that support? The phrase "learning by doing" is often used for students, but it also works for teachers. In the evaluation of several federally funded Australian projects, strong support has been found for teacher change and development by being involved in school–community projects. The first of these projects was the Science Awareness Raising Program (Rennie and ASTA 2003), followed by the School−Community Industry partnerships in science projects (SCIps) (ASTA 2005), both led by the Australian Science Teachers Association (ASTA). In these projects, teachers in one or more schools worked with community members on a science-related issue that was important to the community. Successful projects at the primary, middle and secondary levels blurred the school–community boundary. They consumed considerable time and effort, but were found to be rewarding for teachers, students and parents, who were often key contributors from the community. Invariably, the students were very engaged and produced evidence demonstrating considerable learning, and often that learning was shared with the community.

Similar findings emerged from the larger scale, Australian Schools Innovation in Science, Technology and Mathematics (ASISTM) project (Tytler et al. 2008), in which schools worked with outside experts on innovative projects in their communities. Renewed self-confidence, content knowledge and confidence with science processes were gained, indicating that for many teachers participation in their ASISTM project was "a very potent and successful form of professional learning for teachers" (p. 39).

Rennie (2006, p. 9) argued that there are several important guidelines for effective school–community projects. Successful projects

- are based on some issue/stimulus which comes from within the community and is not imposed.
- require the input of community members to provide local knowledge to contextualise the issue.

- are educative, because they focus on science as a way of knowing, thinking and acting, and model science inquiry (working scientifically).
- are integrated into the school science curriculum and thus legitimise participation by students and teachers.
- involve negotiation and decision-making with the community in regard to social, political and economic factors, differing perspectives from different groups, and information collected (both local and science-related).
- have a tangible outcome to indicate when the project is complete and demonstrate that it has achieved something worthwhile.

In sum, such programs demonstrate that when the school–community boundaries are blurred, there is enhanced engagement and interest from students, and considerable professional learning for teachers. But this learning comes at a price. Working over boundaries is time-consuming and requires effort and commitment by the teachers and community members involved. Given this, such programs must be allocated a real place in the science curriculum, a place made possible by lessening the science disciplinary content by judicious selection of what is most meaningful for the students involved.

Final Word

Mrs R. joined the *Scientists in Schools* project when she was given the role of science coordinator in her primary school. She was resolved to learn more about teaching science, and wanted to promote science in her school. She believes that her partnership with Dr C. has improved her own pedagogical content knowledge as well as providing her class with exciting and challenging activities (some of which involved growing 15 different kinds of potatoes!) they otherwise could not have experienced. Allowing Dr C. into her classroom and working with him in a flexible and respectful way, reaped considerable benefits for Mrs R., Dr C. and her class of Year 4 students (Rennie and Howitt 2009). In terms of the raising students' interest and perceiving relevance in science, the *Scientists in Schools* project has worked well. It is appropriate to give the final words of this chapter to one of the 9-year-old girls in the class who, as part of the project's evaluation, wrote:

> Dr C has changed my life, the way I think about scientists. I thought science was boring, but I was wrong. If you think about it, if you put your mind to it, science is quite cool. As I said before, science has changed my life!

References

Aikenhead, G. (2006). *Science education for everyday life.* New York: Teachers' College Press.

Australian Science Teachers Association. (2005). *SCIps school industry partnerships in science: Final report.* Canberra: Department of Education, Science and Training. (Available at http://www.asta.edu.au/scips/gui/files/final_report.pdf)

Bartholomew, H., Osborne, J., & Ratcliffe, M. (2004). Teaching students “ideas-about-science”: Five dimensions of effective practice. *Science Education, 88*, 655–682.
Bell, P., Lewenstein, B., Shouse, A. W., & Feder M. A. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits.* Washington: The National Academies Press.
Bernstein, B. (1971). On classification and framing of educational knowledge. In M. F. D. Young (Ed.), *Knowledge and control: New directions for the sociology of education.* London: The Open University.
Braund, M., & Reiss, M. (Eds.). (2004). *Learning science outside the classroom.* London: RoutledgeFalmer.
Corrigan, D., Dillon, J., & Gunstone, R. (Eds.). (2007). *The re-emergence of values in science education.* Rotterdam: Sense.
Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. In G. J. Kelly, A. Luke, & J. Green (Eds.), *What counts as knowledge in educational settings, disciplinary knowledge, assessment, and curriculum. Review of Research in Education, 32*, 268–291.
European Commission. (2007). *Science education now: A renewed pedagogy for the future of Europe.* Brussels: European Commission, Directorate-General for Research.
Fensham, P. J. (1985). Science for all: A reflective essay. *Journal of Curriculum Studies, 17*, 415–435.
Fensham, P. J. (2008). Science education policy-making: Eleven emerging issues. A report commissioned by UNESCO, Section for Science, Technical and Vocational Education. http://unesdoc.unesco.org/images/0015/001567/156700e.pdf. Accessed 10 Oct 2008.
Fensham, P. J. (2009). The link between policy and practice in science education: The role of research. *Science Education, 93*, 1076–1095.
Gardner, P. L. (Ed.). (1975). Science and the structure of knowledge. In P. L. Gardner (Ed.), *The structure of science education* (pp. 1–40). Hawthorn: Longman.
Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: A research report.* Canberra: Department of Education, Training and Youth Affairs.
Jenkins, E. (2007). School science: A questionable construct? *Journal of Curriculum Studies, 39*(3), 265–282.
Layton, D., Jenkins, E., Macgill, S., & Davey, A. (1993). *Inarticulate science? Perspectives on the public understanding of science and some implications for science education.* Nafferton: Studies in Education Ltd.
Levinson, R., & Turner, S. (2001). *Valuable lessons: Engaging with the social context of science in schools.* London: The Wellcome Trust.
National Science Council. (1996). *National science education standards.* Washington: National Academy Press.
Osborne, J. (2007). Science education for the twenty first century. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(3), 173–184.
Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections.* London: The Nuffield Foundation.
Osborne, J., Duschl, R., & Fairbrother, R. (2002). *Breaking the mould? Teaching science for public understanding* (a report commissioned by the Nuffield Foundation). London: The Nuffield Foundation. (Available at www.kcl.ac.uk).
Ratcliffe, M., & Grace, M. (2003). *Science education for citizenship.* Maidenhead: Open University Press.
Rennie, L. J. (2006, August). The community’s contribution to science learning: Making it count. Plenary address to the ACER Research Conference 2006, “Boosting science learning—What will it take,” Canberra.http://www.acer.edu.au/documents/RC2006_Rennie.pdf. Accessed 13 March 2007.
Rennie, L. J. (2007). Learning science outside of school. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 125–167). Mahwah: Lawrence Erlbaum Associates.

Rennie, L. J., & Howitt, C. (2009). “Science has changed my life!” Evaluation of the scientists in schools project. A report of its evaluation. http://www.scientistsinschools.edu.au/evaluation.htm. Accessed 15 April 2009.

Rennie, L. J., & The Australian Science Teachers Association. (2003). *The ASTA science awareness raising model: An evaluation report prepared for the Department of Education Science and Training*. Canberra: ASTA. (Available at http://www.dest.gov.au/sectors/school_education/publications_resources/profiles/science_awareness_raising_model_evaluation.htm).

Rennie, L. J., Venville, G., & Wallace, J. (2010). Learning science in an integrated classroom: Finding balance through theoretical triangulation. *Journal of Curriculum Studies,* 1–24. First published on: 02 December 2010 (iFirst).

Roberts, D. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). Mahwah: Lawrence Erlbaum Associates.

Ryder, J. (2001). Identifying science understanding for functional scientific literacy. *Studies in Science Education, 36*, 1–42.

Saunders, K. (2010). Engaging with bioethics: A professional learning programme for science teachers. In A. Jones, A. McKim, & M. Reiss, (Eds.), *Ethics in the science and technology classroom: A new approach to teaching and learning* (pp. 103–128). Rotterdam: Sense.

Schreiner, C., & Sjøberg, S. (2007). Science education and youth’s identity construction—two incompatible projects. In D. Corrigan, J. Dillon, & R. Gunstone (Eds.), *The re-emergence of values in science education* (pp. 231–247). Rotterdam: Sense.

Stocklmayer, S. M., Rennie, L. J., & Gilbert, J. K. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education, 46*, 1–44.

Tytler, R., Symington, D., Smith, C., & Rodrigues, S. (2008). An innovation framework based on best practice exemplars from the Australian School Innovation in Science, Technology and Mathematics (ASISTM) Project. Canberra, Australia.http://www.dest.gov.au/sectors/school_education/publications_resources/profiles/innovative_framework_asistm.htm. Accessed 1 June 2009.

Venville, G., Rennie, L., & Wallace, J. (2004). Decision making and sources of knowledge: How students tackle integrated tasks in science, technology and mathematics. *Research in Science Education, 31*(2), 115–135.

Venville, G., Rennie, L. J., & Wallace, J. (in press). Curriculum integration: Challenging the assumption of school science as powerful knowledge. In B. J. Fraser, K. Tobin, & C. McRobbie (Eds.), *Second international handbook of science education*. Dordrecht: Springer.

Venville, G., Sheffield, R., Rennie, L., & Wallace, J. (2008). The writing on the classroom wall: The effect of school context on learning in integrated, community-based science projects. *Journal of Research in Science Teaching, 45*(8), 857–880.

Venville, G., Wallace, J., Rennie, L. J., & Malone, J. (2002). Curriculum integration: Eroding the high ground of science as a school subject. *Studies in Science Education, 37*, 43–84.

Springer
http://www.springer.com/978-90-481-3926-2

The Professional Knowledge Base of Science Teaching
Corrigan, D.; Dillon, J.; Gunstone, R. (Eds.)
2011, XVI, 326 p., Hardcover
ISBN: 978-90-481-3926-2