# Making Science Beyond the Classroom Accessible to Students

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This chapter is based on the premise that the science students learn at school should enable them to become scientifically literate citizens, irrespective of what their future career ambitions may be. Students are best served by a school science curriculum that equips them with the knowledge, skills, desire and confidence to deal effectively with the science-related issues that arise not only during their school years but in their adult lives as well. They should be able to access science information when needed, assess its relevance, and apply it to the situation or problem at hand (see also Fensham, this volume). To learn to do this, students need to experience explicit connections between the science they learn in school and the science that happens outside of school. This chapter uses three case studies to illustrate how school-community programmes can promote students' access to science beyond the classroom and contribute to the development of scientific literacy.

## Scientific Literacy as a Goal of Science Education

Scientific literacy is an often-used but ill-defined goal of science education. Feinstein (2011) referred to "the endless definition of and rationales for science literacy … it has come to mean everything and nothing" (p. 170), and asked, "What can be done to revitalise science literacy, to take it beyond the realm of politically useful slogans and make it into a goal that is both realistic and worthy?" (p. 170). Earlier, Roberts' (2007) analysis of this term suggested two "Visions" of scientific literacy/science literacy: Vision I is obtained by "looking inwards at the canon of orthodox natural science, that is, at the products and processes of science itself" (p. 730). Vision II looks outwards, to "the character of situations with a scientific component, situations

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that students are likely to encounter as citizens" (p. 730). Traditionally, science education has been discipline-based, concerned with the canonical concepts of science and its processes; a Vision I approach. We might think of this as the science used by scientists. However, people using science in everyday life do not think of themselves as scientists. Research, such as that by Layton et al. (1993), shows that people search out science-related information that is relevant to their needs and then reconstruct it into a form that has meaning to them and is useful for their purpose. People who do this effectively might be considered scientifically literate in the sense of Roberts' Vision II. Feinstein took a rather similar view by arguing, "we can salvage science literacy—make it into a meaningful educational goal instead of a mere slogan—by redefining it according to research on the actual uses of science in everyday life" (p. 183). He suggested a convergence between science education and public engagement with science; that science literate people "have learned to recognise the moments when science has some bearing on their needs and interests and to interact with the sources of scientific expertise in ways that help them achieve their own goals" (p. 180). Science educators generally agree that science learned should be useful and relevant, but how can science education move students towards this kind of scientific literacy?

Following a review of science education in Australia, Goodrum et al. (2001) argued for a focus on scientific literacy in school science curricula. They described scientifically literate people as 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. This view of scientific literacy holds promise. While acknowledging the importance of science concepts and processes (Roberts' Vision I), it is strongly underpinned by genuine engagement with science in daily life (Roberts' Vision II). It embodies the kinds of skills and abilities that enable people, including students, to cope with science-related issues in life both within and beyond the classroom. Given that most people will be non-scientists, it also fulfils what Norris (1995) regarded as "one of the primary goals of teaching science in school … to teach these people the wherewithal to deal intelligently with science and scientists despite their lack of scientific expertise" (p. 202).

If thinking about scientific literacy is expanded to embrace the huge range of informal contexts beyond the classroom, two issues about science must be considered. First, unlike the unidisciplinary approach to science represented in school timetables and frequently enacted in science classrooms, science in the "real world" is multidisciplinary. Understanding science-related community problems and finding answers to them requires integrating knowledge from science with knowledge from other subjects (Venville et al. 2008). Second, science in the real world is neither objective nor value-free; it is inflected with social, economic, and political values (Corrigan et al. 2007). Relevant science concepts will be integrated not only with different subjects but entwined with other, human issues at work in the local environment. Thus dealing with science in the community introduces values, such as social and environmental responsibility, in association with the relevant science concepts.

To learn how to tackle multidisciplinary, value-laden problems, students need opportunities to learn and practise using their knowledge and skills in circumstances beyond the classroom. Explicit connections need to be made between school knowledge and community issues. This means bridging the gap between school science and science as it is practised in, and impinges on, life outside school. Research and experience have shown this bridging is not easy (Rennie et al. 2012). To help students learn multidisciplinary skills, teachers themselves need to be competent in using them, and be able to deal with socio-scientific issues (Rennie 2011). They also need to find time in an overcrowded curriculum to bring the school and community closer together, because making links between them is essential to bridging the gap.

There are many kinds of school-community links. The simplest occurs when students access information from community sources to assist them to complete set tasks for school, such as seeking information from the local council for an assignment on weed control. The most difficult to achieve are those that entail a high level of involvement with, or contribution to, the community. Examples include long-term partnerships with community institutions, such as universities, museums . or wildlife centres. Here the linking activities involve more than the seeking or exchange of information, they involve interaction between partners, usually to the benefit of both. Activities in such partnerships take considerable time and effort for teachers to organise and implement and often require funding beyond what schools can afford. Consequently, most of these programmes are externally organised and funded from a combination of government, science-based industry and institutional sources. The specific aims of these programmes vary, but most hope to foster students' interest in science. and motivation to consider a science-related career.

In this chapter, case studies of three established school-community programmes are used to demonstrate the range of externally organised initiatives that aim to connect school students with science and scientists outside school. They are *Mildew Mania* (http://science.curtin.edu.au/outreach/citizen-science.cfm), a university-based, state-wide citizen science programme; Primary Industry Centre for Science Education (www.picse.org), an Australian national programme focusing on primary industries and implemented by local activity centres; and *Scientists in Schools* (www.scientistsinschools.edu.au), another Australian nationally organised, locally supported programme. Each case study includes an overview of programmes of its kind, a description of the specific initiative, its implementation, and the nature of its outcomes with regard to student learning.

## Mildew Mania: A Citizen Science Project for Students

Citizen science can be simply described as "public participation in organised research efforts" (Dickinson and Bonney 2012, p. 1). It capitalizes on the motivation of citizens, including students and families, to be involved in subjects relevant to their own lives and interests, allowing them to collect data to contribute to resolving a science-related issue. There are mutual benefits: much more data can be collected than scientists could manage with their limited time and resources, and citizens may meet or work with scientists, learning both content and skills relevant to the project.

Bonney et al. (2009) proposed three models to encompass the range of projects that involve citizens in science. Most projects are *contributory*, with the public primarily contributing data. In *collaborative* projects, citizens help with design, data analysis, or disseminating findings. In *co-created* projects, at least some citizens are involved in the entire research process. Bonney et al. conducted a meta-analysis to measure the outcomes of several citizen science projects. There were clear indications that participation contributed to people's awareness, knowledge, and understanding of the focus science topic; increased their interest and engagement; and built science-related skills, but Bonney et al. uncovered few robust evaluation findings. They called for greater effort in research and evaluation of the many kinds of citizen science to learn how to build successful models.

Student-scientist partnerships are a contributory model of citizen science, usually based in schools, but frequently involving students in structured activities outside school. Cohen (1998) identified three primary characteristics of student-scientist partnerships:

> Scientists ask and use students to help answer questions [that require] large numbers of strategically positioned observers … students gather and analyse data [for] large-scale projects … that involve authentic and important scientific questions; science teachers are active intermediaries not only for explaining science, but for helping scientists and students implement their research. (p. 1)

*Mildew Mania* is a citizen science project aptly described by these characteristics. Students are requested to collect data for an authentic project, but their participation depends on the willingness of teachers to take part, and students' actions and science learning are mediated by their teacher's oversight of the activities.

## About Mildew Mania

*Mildew Mania* began in 2010 as an initiative of a university research centre for the study of plant pathogens. The focus pathogen is a powdery mildew that infects barley and causes significant reduction in crop yield and quality, with resultant economic loss to the industry. A rapidly spreading mutation in one strain of the mildew is resistant to the commonly used fungicide. This citizen science project was devised by plant scientists to work with school children who could grow a particular cultivar of barley, allow it to become infected with powdery mildew, and then return the mildew samples to the university laboratory for further research. Identification of the pathogen in the students' mildew samples enables scientists to map the geographic distribution of the various "strains" of mildew. Using students' samples, these strains can be grown in the laboratory and tested for resistance to various fungicides. Barley cultivars that are resistant to the particular strains of mildew can also be identified, and plant breeding can create new cultivars with a high yield and genetic resistance to mildew.

*Mildew Mania* has four aims: to collect and test mildew samples from many locations throughout the state; to involve the community in agricultural research and development; to engage students in meaningful science; and to encourage enrolment in tertiary agricultural studies. The project is managed by the university's science outreach programme. Participating schools are provided with barley seeds, instructions and background information, sampling equipment, and reply-paid envelopes. Once mildew is detected on their barley, students email photographs to the scientists for confirmation, then infected leaves placed in agar tubes and swabs of the mildew are posted to the laboratory. During both 2011 and 2012, mildew data collection involved well over 100 classes from across the metropolitan and grain growing areas of the state. The programme continued in 2013.

## *Mildew Mania Case Study*

Data for the case study were collected by two surveys and interviews. Teachers applying to participate in *Mildew Mania* in 2012 responded to a survey about their expectations. In addition, six teachers who had participated twice in the project were surveyed by email about their experiences. Semi-structured interviews were held with the Science Outreach Manager and three scientists in the research centre. Resources and materials available to teachers were also reviewed.

### Findings from the Pre-participation Survey

Prior to their participation in 2012, teachers were asked: Why do you want to participate in *Mildew Mania*? What are you expecting from *Mildew Mania*? How do you think your class will benefit from this programme? The anonymous answers from 38 secondary and 22 primary teachers were available for analysis. The responses to each question were read carefully to identify themes. Results were collapsed across these questions because all answers referred to benefits for students. A total of 182 ideas, opinions or views were coded into 21 categories with most teachers' responses receiving more than one code. The 21 categories were clustered into five themes that accounted for nearly 92 % of the coded ideas. The themes were labelled 'Relevance', 'Investigative Skills', 'Beyond School', 'Real Science', and 'Engagement', and are described in Table 1.

There was a strong focus in teachers' views that *Mildew Mania* deals with real science concerning an important community issue, providing opportunities for students to develop their investigative skills (a significant part of the Australian school science curriculum) in a meaningful, relevant context that students find

**Table 1** Description of student benefit themes from the 2012 teachers' pre-participation survey for *Mildew Mania*

| Theme | Description of theme | Total codes |
|---|---|---|
| Relevance | Doing science that is meaningful, real-life, relevant to local area, useful, important | 46 (25.3 %) |
| Investigative skills | Participating in hands-on science that will develop students' science process skills; ties in with investigation in the science curriculum | 44 (24.2 %) |
| Beyond school | State-wide, community-based project, something different that extends students | 31 (17.0 %) |
| Real science | Participating in real science/research, connection with scientists | 29 (15.9 %) |
| Engagement | Students will be (or were last time) motivated, engaged, and taking responsibility for their work | 17 (9.3 %) |

engaging. One primary school teacher's expectations summarised many of these themes:

> (i) Children to be engaged; (ii) Children to learn about monitoring plant growth and looking after plants; (iii) Children to understand a bit about the impact that something so small can have on our farmers and economy; (iv) Biology understandings; and (v) A bit of pride in helping do real science.

Another teacher wrote:

> It provides students' input into a broader science project, giving them the understanding that science goes beyond the classroom and lab and has influence on everyday life right here in their backyard.

Responses to a fourth question, "How do you think your teaching will benefit from this programme?", were more focused on benefits to the teacher. Ten teachers new to *Mildew Mania* were reluctant to commit themselves to benefits, but 40 made 52 suggestions that were coded into 12 categories. Table 2 reports the five themes into which these categories were clustered, but only the first three of these (totalling

**Table 2** Description of teacher themes from the 2012 teachers' pre-participation survey for *Mildew Mania*

| Theme | Description of theme | Total codes |
|---|---|---|
| Professional learning | Extending teachers' knowledge base, improving confidence and providing background for "big picture" discussions with students | 17 (32.7 %) |
| Resources | Additional resources to improve teaching | 7 (13.5 %) |
| Curriculum fit | Project will fit into science curriculum | 5 (9.6 %) |
| Students' skills | Opportunities for students to develop investigative skills and independence | 12 (23.1 %) |
| Real world project | Opportunities for students to be connected to science in the real world in a meaningful way | 11 (21.2 %) |

55.8 % of codes) are benefits to the teachers; the other two (44.2 %) are potential benefits that the teachers can see for their students.

Although it was not possible to tell exactly how many responding teachers had previously participated in *Mildew Mania*, their responses indicated that many had. For example, one teacher commented:

> I participated last year and found doing action research for a state wide tertiary driven initiative very useful for giving my students relevance and purposefulness to their science experience.

Teachers were keen to find ways to connect their science classes to a context broader than their own interpretations of the curriculum, and they expected participation in *Mildew Mania* to provide this opportunity. They also foresaw additional resources for their classrooms.

## Findings from the Teacher Email Survey

A total of 165 teachers participated in *Mildew Mania* in 2011 and/or 2012. Six of the 45 teachers who participated in both years and were enrolled for 2013 were invited by email to respond to questions about their experiences with the project, and what benefits or problems arose. All agreed and their demographics (using pseudonyms) are reported in Table 3. The proportion of rural and metropolitan schools, and of primary and secondary teachers, is similar to the sample enrolled in *Mildew Mania*.

The first questions asked, "What benefits did you hope to gain from participation in the *Mildew Mania* programme for you and for your students? Were they achieved?" All teachers noted the importance of having students collect data in a real science investigation with wider significance. Alice, in a small district high school, hoped to bring some contextual science into her programme, using science processes to collect some real data. She believed this goal was partially achieved, but thought she put insufficient emphasis on observing and recording data at regular intervals. Sally was pleased the programme aligned with the Australian curriculum

**Table 3** Demographics of teachers responding to an email survey about *Mildew Mania*

| Attribute | Albert | Alice | Sandra | Evelyn | Sally | Donald |
|---|---|---|---|---|---|---|
| School | Rural primary | Rural high | Metro primary | Metro primary | Metro primary | Metro high |
| Students involved | Years 6–7 | Years 8–9 | Years 6–7 | Years 1–7 | Years 5–7 | Years 8 and 10 |
| Success in growing mildew | 2011; no, weather too dry | 2011; yes | 2011; yes | 2011; yes | 2011; yes | 2011; yes |
| | 2012; yes | 2012; no, frost killed barley | 2012; no, teacher absence | 2012; no, ravens pulled up seedlings | 2012; yes | 2012; yes |

and that it allowed “students to get in touch with nature, the problems for farmers and the solution provided by scientific research”. Donald, referring to his city high school students, summed up other teachers’ positive views:

> The benefits I hoped to gain were really through seeing the students become involved in a project where they were contributing original data to a research project addressing an issue of concern. I enjoyed seeing both classes being so involved in setting up the project, monitoring the plants’ growth and collecting the data needed. Their involvement gave them an idea of how research studies are designed, how data are collected and the need for careful control of variables. They also enjoyed spending time outside the Science laboratories! They were pleased to know that their work was contributing to such an important project and gave them firsthand experience of the ways by which Science is used to solve problems of this nature. They also learned that crop plants are vulnerable to attack by fungi, and that fungicides won’t always be effective in treating all strains of a particular fungus.

Not all classes were successful in growing mildew for the reasons shown in Table 3. Sandra’s Year 6 and 7 students were excited at the first signs of what they thought was mildew growing on their barley and even more excited when the university confirmed their diagnosis.

Teachers were asked: “Do you think participation assisted students to make links with science outside of school? If so, in what ways?” There was strong agreement. Albert’s students, who lived in a grain-growing area,

> responded very positively to feedback or contact from the scientists. The project helped them to make links, connections to people who work within the community doing science but not necessarily seen as scientists. They can see how this type of science plays an important role in industry such as agriculture and the impacts it can have on the long-term viability of these industries.

Sandra’s city-living Year 6 and 7 students realised the social implications of farming:

> I’m sure before [*Mildew Mania*] that few students linked science investigations with farming. Their knowledge of crops grown in Western Australia was also very limited. They developed an appreciation of how difficult it is for farmers to sustain a living—relying on weather to provide the right growing conditions and how difficult it would be for farmers both financially and emotionally to lose their crops. One group of students was devastated to find snails had eaten their whole pot of barley plants.

Evelyn noted:

> Students engaged enthusiastically in the hands-on science investigation and expressed appreciation of the challenges faced by farmers. They learnt about economic and social implications, as well as other topics that came up as a result of the investigation, such as the pH of soil.

Teachers agreed that sufficient information was available from the university about the results and the value of students’ efforts. They found a slide presentation about how the samples are used and maps of the distribution of results very helpful. Finally, teachers were asked: “Overall, were you pleased with the outcome of your participation? Why or why not?” All teachers were positive, and Albert’s response echoed other teachers’ comments:

> Yes we are pleased with our participation; the students now want to know when they can start this year's mildew project and value that they are contributing to science that will assist farmers. The students accept ownership of the trial and make sure it is cared for, they check for the required signs, collect the samples and forward the data and evidence. These types of projects make science the real thing for the students.

### The Scientists' Views of *Mildew Mania*

*Mildew Mania* was designed to supply enough samples to facilitate an effective programme to develop a genetic means of controlling powdery mildew. The research leader reported that the first 2 years generated a large amount of data on the distribution of virulence in the mildew and fungicide resistance that was now being incorporated into scientific papers.

*Mildew Mania* was successful, but two problems arose. In 2011, mildew samples were returned from about 70 % of schools. However, the quality of the samples was compromised by slow postal return or the leaf samples "drowning" in the agar solution. Nevertheless, about a quarter of the samples were viable and from these around 100 "isolates" (individual samples of mildew) were able to be propagated and their DNA sequenced. The second problem was that most participants were city schools, so their mildew samples had limited value in mapping the geographic distribution of the pathogens. Consequently for 2012, more precise instructions for sample collection were given to schools, and encouragement given for schools in agricultural areas to participate.

When it became clear that the fungicide-resistant mildew pathogen was wide-spread over the state's grain-growing area, the research centre obtained industry funding to combat this disease. In 2013, the project was extended (as *Mildew Mania Plus*) to 20 rural schools located in grain-growing areas. A scientist visited schools to facilitate high-quality sampling of several barley cultivars, some treated with fungicide. *Mildew Mania* continues in parallel, managed by university outreach.

## The Primary Industry Centre for Science Education (PICSE): An Example of Student Work Placements

Work placements, internships and apprenticeships allow students to experience science in research contexts. Placements .may be for a few hours over a period of time, or full-time over a shorter period. They may be a class requirement during semester or during a summer break, perhaps on a supervised project. There is diversity in the nature of the placement and also in the outcomes. A literature review by Sadler et al. (2010) identified 15 research studies of secondary students in apprentice roles. Students engaged consistently in research activities with a mentor over a sustained period of time (between 2 and 10 weeks); some students worked individually and others in groups. These studies revealed increased students' understandings of the complexity and uncertainty of scientific research, and the time and attention to detail required to gather valid data under sometimes difficult conditions. Most of the apprenticeships had a goal of promoting aspirations for a career in science, and Sadler et al. found that some students already interested in a science career became aware of more choices in the field. They urged that more research attention be given to direct and valid measures of outcomes.

Burgin et al. (2012) investigated the outcomes for 18 grade 11 and 12 students (age about 16–17) who worked on a mentored science project in a summer programme. All students learned science content, but interest varied with how much choice students had with their projects, whether they were in a research group or working individually, and their understanding of the reason for their given project. Burgin et al. suggested that students already interested in science would gain most benefit from such apprenticeships. The Primary Industry Centre for Science Education provides scholarships for interested students to learn more about science careers in which a central component is work placement.

## *About the Primary Industry Centre for Science Education*

The Primary Industry Centre for Science Education (PICSE) aims "to attract senior high school students into tertiary science studies and to increase the number of skilled professionals in agribusiness and research institutions" (http://www.picse.net/HUB/overview.htm). It is funded nationally by the Australian government and several industry bodies and cooperative research centres. There are PICSE activity centres in five Australian states where a Science Education Officer (SEO) organises local delivery of the PICSE model by coordinating collaboration between the centre, school communities and primary industries. The components include professional development and resource materials for science teachers (see http://www.picse.net/HUB/resources.htm), and a scholarship comprising a camp and industry placement for senior students.

## *The PICSE Camp and Industry Placement Scholarship Case Study*

This case study focuses on the camp and industry placement at an activity centre hosted by a university. Twelve students (selected from 34 applicants) attended a week-long camp in December 2012 and a 5 day work placement at a local primary industry prior to beginning university studies or returning to school in 2013. The data included documents, students' reflective reports on their camp and placement experiences, and interviews with the PICSE SEO and three students. Student interviews explored the opportunities students had at school to make connections between learning in their science classes and how science "works" in the community, how the PICSE camp and industry placement compared with school in making such connections, and how students' experiences affected their study choices.

During the PICSE camp students resided in on-campus housing and each day attended hands-on activities at the university or were transported to other sites for tours and participatory demonstrations. Each evening the students dined together and enjoyed various entertainments. Activities and tours covered disciplines associated with primary industries, and included short sessions on science communication, public speaking, photography, and career choices.

Ten student placements were related to primary industries at the university or government laboratories or field-sites, one was at a country newspaper and the other at the university science outreach. Students worked alongside primary industry scientists participating in their day-to-day activities. Following the placements, students attended a "reporting back" evening, gave a presentation about their experiences, and handed in their reflective report.

## Findings from Students' Reports

Applicants for PICSE scholarships are able students already interested in science, and interpretation of their data must keep this in mind. Four students were in Year 11 and eight in Year 12; three boys and three girls attended a metropolitan school, four girls and a boy attended agricultural colleges in rural areas, and one girl attended a geographically remote coastal school.

Students enjoyed their camp experience, with all commenting on some aspect they particularly enjoyed, such as the passion of the speakers and the company of other "friendly and smart" students. One girl summed it up thus: "In a nutshell, the camp had everything: amazing people, great activities and plenty of science, all adding up to a truly unforgettable week".

Every student, including those attending an agricultural college, commented on the camp as an eye-opening experience that broadened their understanding of the importance of the science involved, and the variety of careers available in primary industries. As one city girl remarked,

> Agriculture is not just a farmer on a farm farming, but the collaboration of a range of jobs and people, with some being in the field, some being in a lab and some being in an office and each job being as important as the next.

A boy from an agricultural college wrote that his experiences

> … not only expanded my knowledge of science and primary industries, but gave a real in-depth understanding of why we as a country rely on science from everyday situations to global issues.

Other aspects students appreciated included the different tours of laboratories and other sites. They enjoyed the hands on activities, in particular making noodles “from scratch” and ice-cream using liquid nitrogen as the coolant. Five students drew attention to the importance, particularly in a global situation, of ensuring food security. A city girl wrote that the camp

> … greatly increased my understanding and appreciation of the processes and effort behind getting safe and good quality food delivered onto our plates—something I have often taken for granted. These talks also highlighted the integral role of food in our society, along with the challenges faced in terms of maintaining supply in the face of surging population.

In most placements, students moved between different sections of the work-place and joined in a range of activities, often including both laboratory and field work, experiencing the breadth of science carried out in that particular industry. Students commented that this strategy enabled them to get a “bigger picture” of industrial processes; the importance of “all of the people in the chain working together”, as one student put it. All students commented positively on the passion, enthusiasm, and friendliness of helpful mentors or supervisors.

More than half of the students experienced activities requiring a high level of cleanliness and sterilization of equipment, and/or careful documentation and storage of specimens, finding this an important part of science they had not considered previously. Those students in laboratory situations were delighted to find themselves using highly specialised equipment to perform analyses or other techniques that were new to them.

Although the camp experience had given students an appreciation of the range of careers available in the sciences, particularly agricultural sciences, the work placement gave them a real feel for what scientists actually do, and the conditions under which they work. Although a lot of passion and hard work was involved, students found it could also be fun. One Year 11 student was excited that “having spent a year at agricultural college I was able to see how what I had learnt there was being researched and applied in industry”. She also noted that, “my placement helped me to realise that opportunities for essential research can be constrained or promoted by political agendas and that there is a need to abide by ethical standards that may restrict experimentation and research”. Three other students commented on learning about the important role of science in creating a viable future for the planet.

## Findings from Interviews

Three students were selected for interview, as a proportional sample of the scholarship holders based on gender and location of their school. Paul and Ann from metropolitan schools and Jane from a rural agricultural college were nearing completion of the first semester of a university science-based bachelor’s degree. All were enjoying their studies. The face-to-face interviews were structured around three questions.

The first question asked: “What kinds of opportunities did you have while at school to make connections between what you were learning in your science classes and how science ‘works’ in the community?” Paul had taken biology and physics at school, and Ann studied biology and chemistry. Both stated that their textbooks used a lot of real world examples to try to make the subjects meaningful. They believed that their teachers tried to make connections but were restricted by the need to complete the syllabus. Paul found subjects more interesting when he could see how science was used outside of the classroom, and Ann liked to see links, so that she could “see the big picture and how the sciences fit together”. A highlight for each student was a biology field trip during Year 12. Both trips had strong environmental and ecological themes and the students drew on their field-trip experiences to provide examples of biological processes in school assignments and examinations. In junior school, Ann was a member of Bushranger Cadets, an afterschool science club focused on environmental issues. It included theoretical work and many activities outside of school time, including camping. Ann believed her participation helped her to understand biology at school.

Jane had different experiences at agricultural college. She completed multi-disciplinary subjects in animal and plant production, and her courses were focused on livestock. Having grown up on a farm with sheep and large-scale cropping, cows and fodder were new, and she “learned how cattle and fodder worked by heart”. Much of Jane’s school-work was conducted out of doors, with many field-trips to various agricultural places, so she believed that her school science was closely linked with science outside of school.

Students were asked: “Has your PICSE camp and placement given you any advantages, or other assistance during your first semester at the university? If so, what?” All agreed that the camp gave them a head start on finding their way around the university campus, but mostly they wanted to talk about how much they enjoyed being with other science-interested students and having people from the university or industry giving the sessions.

Students enjoyed their placements, particularly participating in a variety of activities which gave them a range of experiences. Ann did some work similar to the people at the grain industry where she was placed, but also “just helped”. She could see the processes that were used in the industry and how the parts fitted together. She “enjoyed the laboratory work and other practical things, because they make more meaning”. Paul found that the “tasks were helpful but also sciencey”; he felt he was doing real science. “Sure, I was just cleaning ponds,” he said, “but I learned so much about maintaining the chemical balances in the water, about feeding and temperature and growth of fish.” He “really loved” the aquaculture part of his placement and has since set up his own aquaponics at home. Jane’s placement at the state’s botanic gardens exposed her to the broad field of research and restoration science involved in conservation and land management, and also the importance of health and safety in the laboratory and field trials. She found this a nice complement to her agriculturally-based school activities.

Finally, students were asked: “How do you think the PICSE experience contributed to your career plans?” Ann had always wanted to do something in science that "definitely involved investigating", but also involved people. Her experiences in Bushranger Cadets and her placement, particularly the laboratory work, convinced her to pursue biology. She enrolled in molecular genetics and biotechnology and saw her future in this area. Jane liked to have an agricultural focus in whatever she was doing. When her family moved to a city she really missed farm life and requested to attend an agricultural college. Although she did not have a specific focus in her agribusiness degree, she "will see what turns up". Paul was always interested in biology and his scholarship revealed "what an incredible range of jobs there are in agriculture". Through meeting a scientist at the PICSE camp, he found a holiday job in the grain industry. His final comments demonstrate his appreciation for understanding the links between theory and practice:

> You can know how a plant works, but it's still just a plant. When you want to feed it to cattle, you have to know about micro-nutrients and macro-nutrients, and how to grow the best feed plants; better plants, more beef!

## The Scientists in Schools (SiS) Project: Teacher-Scientist Partnerships Designed to Benefit Students

Scientists visiting classrooms is a popular means of providing closer links between school science curricula and real-world science and scientists. Outreach programmes supported by universities, museums, . and other non-profit organisations, aim to stimulate students' learning, interest in science., and consideration of science careers by providing enthusiastic scientists who offer hands-on workshops or other interactive activities for students. Laursen et al. (2007) described an established Danish programme where a "science squad" of graduate students presented science-based enrichment activities for K-12 students and teachers. Pedretti et al. (2006) evaluated another established programme in which volunteer scientists offered half-day workshops in K-8 classrooms. Although in both cases the outreach was brief, the researchers found that these interventions could enhance students' attitudes about and interest in science, and assist them to relate science to real life; this finding was particularly so for girls, English language learners, and low socio-economic status students (Shanahan et al. 2011). A qualitative study of a week-long programme about nanotechnology in two classes of 10th grade students by Painter et al. (2006) revealed that such programmes could also address stereotypes about scientists.

Teacher-scientist partnerships involve a relationship more enduring than the brief encounter of a scientist's visit, and repeated visits could be more beneficial for students' learning. Some partnerships are aimed specifically at enhancing teachers' professional knowledge in the belief that it will spill into their teaching practice. Drayton and Falk (2006) reviewed several year-long partnerships in which teachers carried out projects mentored by scientists and found that success revolved around careful negotiation of the scientist's expertise, the teachers' interests, and a clear purpose for the project. Of interest in this chapter are partnerships formed for the direct benefit of students, but it is worth noting that teacher-scientist partnerships also offer effective professional development for teachers and considerable learning experiences for scientists (Falloon and Trewern 2013; Rennie 2012).

## *About the Scientists in Schools (SiS) Project*

The Australian *Scientists in Schools* (*SiS*) Project aims to establish continuing teacher-scientist partnerships that bring real-world science into classrooms, inspire and motivate teachers and students, and increase scientists' engagement with the public to raise science awareness and knowledge about science careers. *SiS* is government-funded and managed by the Commonwealth Scientific and Industrial Research Organisation—Education Branch. The *SiS* central management team recruits and matches teachers and scientists to make partnerships based on interests and location. The central team provides resources and oversees the programme, but most monitoring of partnerships is carried out by Project Officers (SiSPOs), based in each state and territory, who also support teachers and scientists and arrange networking opportunities. In August 2013, the partnerships in every state and territory totalled over 1,500, with at least one partnership in 12 % of Australian schools.

## *Scientists in Schools Case Study*

Since it began as a pilot programme in July 2007, *SiS* has had three comprehensive evaluations (Howitt and Rennie 2008; Rennie 2012; Rennie and Howitt 2009). They employed a combination of interviews and focus groups with *SiS* team members, teachers, scientists, and students; document analysis; online surveys for teachers and scientists; student work samples; school visits; and observations of *SiS* networking events. These evaluations generated a large amount of data about a large variety of partnerships and this chapter presents some findings focused on students. To give an idea of the range of activity, five successful partnerships are overviewed in Table 4 using data collected by interview and focus groups with teachers and partner scientists during the third evaluation (Rennie 2012). This variety begins to demonstrate the range of additional activities available for students and considerable benefits to teachers, particularly in primary schools.

Teachers and scientists were asked, via an online survey, about the benefits of participation in *SiS* for themselves and for the students. In each evaluation over 30 % of both teachers and scientists responded. Findings for the perceived benefits for students from the third evaluation are reported in Table 5. Although item wordings do not match exactly (the surveys were refined after each evaluation), the results are not only consistent over the three surveys, but become increasingly

**Table 4** Overview of five *SiS* partnerships at November, 2011

| Length of partnership | Year level (s) | Description of partnership |
|---|---|---|
| 4 years | 10–12 | The scientist mainly helps senior students with their major projects. He believes in "real-life practising scientists putting realism into the application of the school science curriculum". The teacher has gained a working knowledge of industry and how science works "at the coal face", which he considers a great advantage to students |
| 5 years | K–6 | The scientist visits this geographically remote school annually, but keeps in touch by students emailing him questions. A wide range of activities has occurred, including a community astronomy night. The teacher has gained in confidence, and now includes the open-ended science and technology investigations from the CREativity in Science and Technology (CREST) Awards programme and other science programmes in her curriculum |
| 4 years | 5–6 | The scientist helps with many diverse activities, including rocks, eye dissections, and electricity. She feels welcome and comfortable in school. The teacher values the ongoing relationship, that the scientist is young and doesn't look like a "comic book scientist". She doesn't hesitate to ask for advice about science |
| 3 years | 12 | In this low SES school, many students have little idea about science as it seems so distant from their background. The scientist aims to get them interested in science and a possible career. He has developed a Year 12 course with the teacher, and outcomes include seven students completing their studies early, increased engagement and school attendance, and more students taking science in Year 11 |
| 4 years | 9 | The scientist works with seven classes of Year 9 students on a 5-week immunology unit aiming to assist students to develop investigative skills and communicate their results to their class. The teacher says students love hearing the perspective of a scientist. Annual surveys of students show very positive responses to activities and science |

positive. This finding suggests that partnership benefits increase with length of partnership.

The top four perceived benefits for students listed in Table 5 show that opportunities to see scientists as real people and to experience doing science with them were perceived by both teachers and scientists as very important outcomes of the partnerships. Increasing students' knowledge of contemporary science was a benefit perceived by more than 90 % of teachers and scientists, just a little more important than "having fun". The next five benefits closely fit the attributes described earlier as contributing to scientific literacy. These skills and abilities received strong support as perceived beneficial outcomes for students. There is likely to be some slippage between perceived benefits and the actual benefits experienced by students,

**Table 5** Perceived benefits of *SiS* partnership to students

| Perceived benefit | % agreement | |
|---|---|---|
| | Teachers | Scientists |
| Opportunity to see scientists as real people | 99.1 | 98.2 |
| Increased knowledge of contemporary science | 93.5 | 90.6 |
| Opportunity to experience science with practicing scientists | 92.3 | 92.4 |
| Having fun | 87.5 | 94.2 |
| Increased ability to recognise and ask questions about the world around them | 87.2 | 88.5 |
| Increased awareness of the nature of scientific investigation | 86.9 | 89.3 |
| Increased awareness of science-related careers | 86.1 | 80.6 |
| Increased understanding about using scientific evidence to make decision about health and the environment | 76.9 | 75.7 |
| Willingness to look to science to make decisions about their own lives | 70.3 | 62.8 |
| Access to science equipment and/or facilities | 66.2 | 53.9 |

*Note* Responses from 382 scientists and 337 teachers

however, student data in the form of surveys, drawings and other work samples in other evaluations strongly supported positive outcomes for the students (Howitt and Rennie 2008; Rennie and Howitt 2009).

In a section asking for further comments on benefits for students, one scientist stated:

> Some teachers have told me (and I have observed) that students will respond to me, and my more informal "lessons", when that same student is not necessarily very responsive in a formal lesson. Also, some children can show knowledge that they have, but which they don't get the opportunity to show in a formal lesson (even some autistic and educationally disadvantaged kids). Also, I am able to pick up misconceptions and discuss them—with teachers and all the class.

An enthusiastic teacher wrote:

> I waited 3 years to get a *SiS* [scientist] and the wait was worth it! This year has seen the elevation of Science at my school to the point where the community engagement is almost overwhelming! Two major science projects have led to great community input, outside sponsorships and a flood of support from the scientific community. … The students are "buzzing" with all aspects of science and I am constantly challenged to improve/expand my teaching practice.

Of course, not all partnerships are overwhelmingly successful, nor do they last forever. A little more than half of partnerships begun since the inception of the programme have closed, with more than three-quarters of them lasting beyond 1 year (Rennie 2012). Around 44 % of closures were due to the changed circumstances (such as relocation) of one or other partner (many of whom began another partnership). Other factors included poor communication or lack of motivation to continue the partnership, often associated with pressures of time.

Unsurprisingly, the consensus of data collected in the evaluations indicated that successful partnerships require stable circumstances in the scientist's workplace and in schools; effective and respectful communication between partners who have realistic expectations of each other; and sufficient time, flexibility and commitment to make the partnership work. Sustaining partnerships requires effort to overcome obstacles, and also support from employers in the case of scientists, and school administrators in the case of teachers.

## Discussion

This chapter began with the premise that the science students learn at school should enable them to become scientifically literate citizens. In the context of scientific literacy articulated by Goodrum et al. (2001), it was argued that opportunities to develop the skills and abilities that enable people to cope with science-related issues in everyday life are promoted when students experience explicit connections between science in school and science beyond the classroom. This is consistent with Feinstein's (2011) view, that science literacy may be "salvaged" by aligning it more closely to the actual uses of science in everyday life, and Roberts' (2007) Vision II of scientific literacy concerned with science situations that people may encounter as citizens. Three case studies of school-community programmes were presented to illustrate how these connections can be made.

According to their teachers, *Mildew Mania* gave students opportunities to perform curriculum-relevant science activities in a context made meaningful because it contributed to a significant project beyond their classroom. Students became engaged with monitoring their barley plants, were exposed to the real-life difficulties farmers face, such as weather and plant diseases, and learned how scientists were endeavouring to control barley mildew. Students attending the PICSE camp were able and science-interested, yet all of them were surprised to discover the breadth of science-related careers in primary industries. Apart from demonstrating "the big picture" of industrial processes, the work placements. also increased students' understanding of the need for attention to detail, safety, and ethical standards in research. They developed some understanding of what scientists do, their working conditions and the equipment they use, and in some cases became aware that political agendas needed to be negotiated.

In *SiS* partnerships, scientists provided students with a range of experiences that were usually additional to, but invariably in greater scientific depth than, what their teachers could provide. Importantly, students found that scientists were real people who could take the time to work with them, often on projects that took them outside the classroom. A large majority of scientists and teachers were convinced that students were developing the attributes of scientific literacy.

These encouraging outcomes are congruent with other research findings. Based on their review of the nature of science learning in the formal school system and in the more informal avenues for learning science, Stocklmayer et al. (2010)

concluded that a stronger school science education results from exploiting the opportunities for science learning that exist outside school. They found that school-community programmes involving social interaction, confidence-building, real-life relevance, and purposeful activity on the part of participants are effective in narrowing the school-community gap. Stocklmayer et al. gave some examples, and there are many more, in many countries, from small projects such as a single teacher's class working with a wildlife centre to monitor birdlife in the local wetland, to international programmes such as GLOBE (the Global Learning and Observations to Benefit the Environment) Programme, which is "a worldwide hands-on, primary and secondary school-based science and education program" (http://www.globe.gov/). GLOBE is nearly two decades old and, according to its website in October 2013, involved 112 countries, 27,000 schools, with over 118 million measurements contributed to the GLOBE database. GLOBE has extensive resources available online, and GLOBE projects are frequently interdisciplinary, integrating science with mathematics, geography, language and art, for example, and providing many avenues for collaboration between schools and students internationally.

From a curricular perspective, it is worth questioning the nature and value of the science students learn in these collaborative, community-based activities. It was noted earlier in this chapter that people tend to reconstruct science-related information into a form that has meaning and is of use to them (Layton et al. 1993). Students do the same. Rahm et al. (2003) explored teacher-scientist partnerships developing school-yard plots and high school students working with scientists to collect data to learn about fire ecology. It was evident that the science that eventuated and made meaning to the teachers and students was not the "scientists' science" or the science espoused in curriculum documents. Rather, it was a science "grounded in the relations between the world of scientists, teachers, and students" (p. 751), a negotiated, constructed science that was meaningful to teachers and students within their own needs, interests, and contexts. Rahm et al. suggested that the emergence of authenticity was assisted by sustained involvement over time and by the participants assuming ownership of the project. In this view, the emphasis is on the processes rather than the products of science and might "lead students toward an understanding of science that has something to do with the real world of theirs and is meaningful to them" (p. 752).

Rennie et al. (2012) argued that knowledge that is meaningful to students has the potential to be more useful to them than strong, disciplinary science knowledge (Roberts' Vision I of scientific literacy) because it empowers students to become more active participants in their world. Consistent with Rahm et al.'s (2003) findings, Venville et al. (2008) found that students' learning outcomes from community connections in an integrated science curriculum tended to be idiosyncratic, and their knowledge of science concepts was likely to be integrated across other subjects as well as issues in their local environment. Rennie et al. (2012) advocated for science curricula to provide a balance between disciplinary and integrated knowledge, and clear connections between local and global knowledge. They proposed

> that STEM curricula provide a mix of disciplinary and integrated knowledge, set in carefully chosen local problems that can be applied to more global issues. The nature of that mix, finding the point of balance and the degree of connection, is dependent on the particular educational context, and will vary from school to school and from place to place. (p. 140)

Such an approach to curriculum would certainly involve the school-community connections that enable students to develop the kind of scientific literacy that underpins this chapter.

Projects such as *Mildew Mania*, PICSE and *SiS* are engaging and provide extended opportunities for students to come to believe that science is useful and relevant to them. Experiencing how science is used in daily life encourages students to recognise the multidisciplinary and value-laden nature of real world science. They can learn to think about how science-related problems and issues relate to them personally and to the community. They may learn to develop a trust in science (see Fensham, this volume) as a way of finding dependable answers to questions about health and the environment, for example. Further, school-community programmes involve collaboration, not only among teachers, students and members of the community, but also collaborative work among the students. This factor, together with the different kinds of science encountered and the variety of people involved in science-related careers, contribute to an understanding of the diversity in the world around them, as well as among students themselves (see Reiss, and also Simon and Davies, this volume).

This positive picture must be qualified by noting that these outcomes do not come "free"; there are costs involved. All three programmes require significant funding to operate and considerably skilled staff to ensure they are managed efficiently. All three rely on scientists volunteering their time, and *Mildew Mania* and *SiS* are successful only in partnership with cooperative, enthusiastic teachers who have the desire, time and space in their curriculum to become involved. The challenge is to encourage more schools, communities and teachers to embrace the opportunities that such programmes offer and enable them to become more mainstream. There are no easy ways to do this, but there are hints available from other research. For example, Rennie (2011) outlined guidelines for successful school-community projects and discussed how teachers could be helped to bridge the school-community gap. Fundamentally, such projects must be perceived as worthwhile by the potential partners. Members of the community are generally reluctant to invite themselves into a school, so even if the proposed project is one that is of vital interest to the community, there is often the need for a "broker" to bring the sides of the partnership together. In the *SiS* project, the management team and the SiSPOs served this role and their participation is essential to establish many partnerships and often to overcome impediments that threatened continuity.

Most importantly, there must be a legitimate place in the science curriculum for such projects which may need adjustment of the primarily content-based objectives to include more affective and social outcomes (see Matthews this volume). School-community projects invariably require the use, and therefore assist the development of, inquiry skills, and they provide ample opportunity to demonstrate that science is a human endeavour, important outcomes of science curricula that help students learn to deal intelligently with science and scientists (Norris 1995). Cementing a place in school curricula, however, needs assurance that students' participation in these projects is assessable. The need for schools to demonstrate accountability by having students achieve in summative assessments drives much of what happens in schools, especially at the senior level. Fair, equitable and authentic assessment, particularly of non-cognitive outcomes, remains problematic and both researchers and practitioners must give more attention to improving it (Corrigan et al. 2013). Fensham and Rennie (2013) pointed out that a profile of achievement over time offers a more authentic representation of what students know and can do than a summative score. Because of their diversity, what students learn from school-community programmes is often idiosyncratic and strongly attitudinal, making it even more important that a range of outcome measures be employed to demonstrate achievements. Broadening the assessment approach to capture the range of student learning would help to justify the inclusion of out-of-school science-related experiences in mainstream science curricula.

Tailoring school curricula to include opportunities that allow students to make connections with science outside of school makes the achievement of scientific literacy a meaningful goal of science education. The evidence presented in this chapter and elsewhere suggests that school-community programmes help students to build the abilities and skills that contribute to a scientific literacy that enables them to cope effectively with science beyond the classroom.

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