PROFESSIONAL LEARNING

Scientific Literacy Under the Microscope

A Whole School Approach to Science Teaching and Learning

Edited by John Loughran, Kathy Smith and Amanda Berry

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Scientific Literacy Under the Microscope

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This series purposely sets out to illustrate a range of approaches to Professional Learning and to highlight the importance of teachers and teacher educators taking the lead in reframing and responding to their practice, not just to illuminate the field but to foster genuine educational change.

Audience:

The series will be of interest to teachers, teacher educators and others in fields of professional practice as the context and practice of the pedagogue is the prime focus of such work. Professional Learning is closely aligned to much of the ideas associated with reflective practice, action research, practitioner inquiry and teacher as researcher.

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John Loughran, Kathy Smith and Amanda Berry
Monash University, Australia

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SECTION 1:
PREPARING FOR SCIENTIFIC LITERACY

SIMON LINDSAY

1. SCIENTIFIC LITERACY

A Symbol for Change

> What kind of science education meets the needs of the minority of students who will go on to become scientists at the expense of the much larger numbers who will not? (Dillon, 2009, p. 3)

PART 1: THE NEED FOR SCIENTIFIC LITERACY

It is often said the only place you see Bunsen burners is in schools. The only place you write up a prac. report is in schools. The only place you wear white lab coats, memorise the periodic table, mix bicarb and vinegar, or make a volcano, is in schools; just in case you ever need to - which most of us don't. Somehow we've remained stuck representing to students an outmoded, irrelevant, and possibly inaccurate perspective of science, given that "society itself has moved on from the "industrial" era through the "knowledge" era, and arguably into an era of design and innovation" (McCann, 2006, p. 40).

Science is a human construct and a function of societal needs. It makes sense that the nature of science changes as these needs vary over time and place. The role of science can be seen to be different in Afghanistan to what it is in Antarctica, different in the Babylonian times than the Renaissance, different in India to what it is at Our Lady of Good Counsel (OLGC), Deepdene Victoria. Science hasn't always looked like "1960s Victoria", and it probably won't look that way in the future.

This revelation that the role and purpose of science can and does change is confronting. The implication for us as educators suggests that we also need to change. It is relatively easy to argue that there is currently a mismatch between the type of science perceived by society, and the type which is currently perpetuated in schools and by policy makers in science education. The change to a new conception and practice of science education is ostensibly slow.

Maybe the reluctance to change stems from the fact that this is the way we were taught science at school, and therefore it is all we really know. Therefore, we invariably hang on to the familiar and known - to the clean clinical lines, the blue lab desks, the Bunsen burners, the text books, the repetition, the memorisation, the order, the power. Maybe it is because the industrial era of science was in many ways so successful, marked by great scientific advancements in transport, electricity, medicine and communication. Thus arguments to suggest a deviation from this are considered by some to be almost sacrilege.

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 3–15.

Maybe it is because the dominant mantra of industrial-era science of reason and rationality and objectivity is just too difficult to challenge. Moves towards a more social conception of science may be seen as "soft" by some scientists and science educators - not "rigorous" nor "well founded in the discipline" or "not enough to prepare one for university". Comments such as these still ring loudly and persuasively in current curriculum debate at the national level further illustrating the divide which exists in Australian science education.

The phrase Scientific Literacy marks that divide well. Notwithstanding all the debate over definitions of scientific literacy, one could argue that at the very least, scientific literacy describes the attempt to move towards a more socially useful conception of science education. Roberts (2007a) makes a helpful distinction between two ways of looking at the aims and purposes of science education in his chapter on scientific literacy in the *Handbook of Research on Science Education*. Roberts notes that:

> ... that there appear to be two schools of thought that characterize all of this definitional activity, based on two 'visions' of the appropriate basis for generating conceptions of scientific literacy appropriate for school science. They are called, simply, Vision I and Vision II. On one hand, Vision I looks inward at science itself – its products such as laws and theories, and its processes such as hypothesizing and experimenting. According to this vision, goals for school science should be based on the knowledge and skill sets that enable students to approach and think about situations as a professional scientist would. Vision II, on the other hand, looks outward at situations in which science has a role, such as decision-making about socio-scientific issues. In Vision II thinking, goals for school science should be based on the knowledge and skill sets that enable students to approach and think about situations as a citizen well informed about science would. (Roberts, 2007b, p. 9)

These visions are underpinned by different values and, at their most extreme, reflect the competing interests that have and continue to influence the school curriculum. At one extreme, there are those whose major preoccupation is the place of scientific content in the curriculum. At the other extreme are those who argue that science education should encourage students to challenge the assumptions underpinning science as a cultural activity (see, for example, Roth & Barton, 2004). The job of policy makers and teachers alike involves reconciling these conflicting visions even though there may be pressure to promote one vision over another (Blades, 1997; Fensham, 1998).

The Rise of Scientific Literacy: The Search for Something Different

Derek Hodson stated as early as 2003 in his paper *Time for action: science education for an alternative future* "it is time to take action on the school science curriculum because it no longer meets the needs, interests and aspirations of young citizens" (p. 643). Levels of student engagement with science, as assessed through the Programme for International Student Assessment (PISA), suggest that Australian students are disaffected with traditional approaches to science teaching (McGaw, 2010).

Table 1.1. PISA 2006 engaging with science rankings (McGaw, 2010)

Aspect of engagement	*Level of engagement/Rank among 57 countries*
General value of science	41st
Personal value of science	37th
General interest in science	54th
Enjoyment of science	45th
Self concept in science	43rd
Future-oriented motivation to learn	42nd
Involvement in science-related activities	53rd

PISA, the worldwide evaluation of 15-year-old school pupils' scholastic performance, performed first in 2000 and repeated every three years, is coordinated by the Organization for Economic Co-operation and Development (OECD), with a view to improving educational policies and outcomes. In 2006, the PISA study had a focus on assessing scientific literacy, targeting both student understandings and levels of student engagement with science. The data is damning with regard to the levels of engagement of Australian students with science (see Table 1.1).

As can be seen from Table 1.1 above, Australia is 54th out of 57 countries with respect to "General interest in science" - meaning only three countries amongst a great proportion of the world have less interest in science than do our students. In my eyes, there is no more urgent argument for change than is clear through this statistic. This outcome related to interest in science is often overlooked in the public announcements of PISA results – we are in fact 3rd or 4th out of 57 when it comes to understanding of science (McGaw, 2010). But a disturbing conclusion we could reasonably draw from these statistics is that while our students may pass the science tests at school, they will be the fastest to drop science from their mindset as soon as possible once they leave school. For a system such as the Catholic Education Office Melbourne (CEOM) which values life-long interest, interaction and engagement in science for all people, as hopefully does the Nation, this has serious implications for the future health and well-being of our individuals and society collectively.

Two main elements appear to be contributing to a renewed need to push for change in science education. Firstly, society is faced with a pressing set of socio-environmental issues including climate change, drought, the energy crisis, obesity, biodiversity, stem-cell research, cloning, nanotechnology, carcinogens and cancer - the list goes on. Secondly, we are awash with information about these issues in the media – on the internet, in the news, on forums, in advertising, mobile phones, social networks, satellite TV etc. - the impact of which is continuous presentation of (science related) information to individuals.

The combination of these two factors means that students need a new set of capabilities to critically engage with science – and it could be argued that these capabilities are different form that gained by previous generations in their years at

school. It also highlights the need for all citizens to be able to engage with science, as opposed to leaving the remedies only in the hands of scientists. There is an argument to suggest that a blinkered view of science and its potential to solve everything has partly caused the environmental predicaments we now face. The distinction between science issues and social issues has become blurred, and the effectiveness of solving social problems with scientific fixes is a cause of long-held discontent. And so the hypothesis goes that if all citizens had capabilities to engage with these socio-scientific issues, then individuals and their societies would be in a better position to solve them in a more informed and effective way.

There have been many attempts over the last 50 years to conceptualise a more socially-oriented version of science education. Such attempts have been codified under different names or headings such as, Science Technology Society (STS), Science Technology Society Environment (STSE), Science for All, Science for Public Understanding, Citizen Science etc. Most, if not all of these conceptions move in some way towards the Vision 2 approach which Roberts described. The term scientific literacy came to prominence as early as the 1950s perhaps as a way of encapsulating these ideas into a new movement in science education.

Since the first use of scientific literacy, science educators and policy makers have gradually reconceptualised the term to such an extent that one author has remarked that it is 'ill-defined and diffuse' (Laugksch, 2000, p. 71). Yet despite this lack of clarity, scientific literacy is now the focus of curriculum standards in many countries and is at the heart of international comparisons of student attainment (and thus of education systems) including the OECD's PISA. Indeed, the term has become so common that McEneaney (2003) has described it as having 'worldwide cachet'.

It may be that the term scientific literacy strikes a chord for many, not because of the clarity or instruction that it provides, but for the simple reason that it coins a phrase for change in science teaching and learning. I believe that the most useful aspect of scientific literacy might be as a symbol for change where change in science education has been notoriously hard to affect. To me it is a symbol for a more human-centred, useful, contemporary notion of science education. It has the potential to act as a banner under which teachers and systems alike can move forward in science - providing a justification, a language, and perhaps direction, for new science teaching and learning. In my work with teachers across schools, it seems that many teachers intuitively feel that the idea of scientific literacy, whatever the specific definition, responds better to the type of 21st century society in which they live, than that which is currently taught as science education in most primary and secondary schools.

It would be difficult to argue with McEneaney's (2003) claim that scientific literacy now has a worldwide cachet. Many countries around are actively trialling different courses and programs under the banner of scientific literacy. The United Kingdom has introduced the Science in the 21st Century program, which involves new courses for secondary school students based around scientific literacy. In the US, Project 2061 has produced the *Benchmarks for Scientific Literacy* and *Atlas of Scientific Literacy* among their reform efforts in science education. In Canada the *STEPWISE* program (Science and Technology Education Promoting Wellbeing for Individuals, Societies and Environments) has been trialled, in the Netherlands the

Algemene Natuurwetenschappen, the *Sinus* program in Germany, and scientific literacy reforms are also afoot in Turkey and South Africa amongst many others.

Just as different countries make decisions about the types of programs and outcomes they want for their students from science education, so too do the different education jurisdictions within countries. Not all education jurisdictions within a geographic region value the same outcomes – indeed, Government, Independent and Catholic systems have different values and beliefs about the nature of quality education for their students, and subsequently about the function and purpose of science education towards this end.

Distinctive Nature of Catholic Schooling

In the CEOM Strategy Plan for the Archdiocese of Melbourne 2006–2010, *One Body: Many Parts*, one of the four stated vision outcomes for students is the capacity for 'Active Citizenship' - to cultivate students who are "empowered to contribute to the common good of society" (p. 1). Within *One Body: Many Parts*, the CEOM's *Learning Centred Schools, A Sacred Landscape* articulates a Learning and Teaching framework for the Archdiocese of Melbourne. It acknowledges that "the rate of tech and social change requires new ways of learning that equip students to be lifelong learners and persons better adapted to the challenges of a rapidly changing world" (p. 6).

A Sacred Landscape describes the distinctive nature of Catholic schooling, in particular that a Catholic school is a "school for the human person and persons". Learning experiences are developed "as a way of creating meaning in life, of developing human potential, and of liberating and empowering individuals to be responsible for their own lives and contribute to the Australian society" (p. 4). It also states that our role as teachers and as a system is to ensure that our students "become free and responsible … capable of engaging with the Australian culture and society ... empowered to enrich this world with direction, meaning, purpose and hope" (p. 4).

These values regarding the nature of learning for our students must in turn shape the way we view and practice science education. More simply, to be true to our values, we must do what we believe; we must practice what we preach.

CEOM Vision for Science Learning

In 2008 a CEOM Science Reference Group attempted to elicit the values of teachers, principals, policy makers and academics in order to formulate explicitly what the system valued from a science education. As a result, the CEOM established a vision for learning in science in the 21st Century. The vision articulates ten desired outcomes for students as a consequence of Catholic science education. A vision centred around the desired outcomes of science education followed on from a recommendation based on commissioned research and reference points (Millar, 2008; Dillon, 2009; Loughran, 2009; CEOM, 2010) within science education so that education jurisdictions could clearly define the nature of outcomes for their own students based upon the values of the system itself. The following Table (1.2) states these outcomes.

Table 1.2. Outcomes for learning in science in 21st century

The outcomes desired for students from a science education in the Archdiocese of Melbourne are, that all students
1. Are bold and confident participants in a constantly changing 21st century world
Students possess knowledge and skills in science which assists in creating resilience to frequent change and emboldens individuals to take action where appropriate. Students are open to change and take measured risks with creativity, open-mindedness, and independent thinking.
2. Appreciate science as a way of knowing about the world
Students appreciate and use science as a way of learning acting, knowing and thinking. They can compare science as a way of knowing with other forms of knowing including religion, history, art etc, and recognize the value of different cultural and indigenous perspectives of knowing about the world. They possess the skills to investigate interesting questions about their world.
3. Possess a sense of awe and fascination about the world
Students possess a continuing sense of awe and fascination about the mystery and beauty of the world in which they live. Students have an appreciation of the complexity of the world around them, and have an ongoing interest in and curiosity about the world and its scientific makeup.
4. Understand the impact of science on society
Students have an appreciation and understanding of the impact of science and technology on everyday life. This includes the incredibly positive outcomes for society which science engenders, but also the negative. Students have a sensitivity to, and awareness of, the place and role of science in different cultural contexts.
5. Are savvy consumers of science
Students are critical of, and sceptical about science and, the ways it is communicated, such as in the media. Students are able to, and have the confidence to, determine what they need to know in science, critically assess information they encounter and critically evaluate how trustworthy is this information. They are able to determine how they will access accurate information and make informed decisions about what will be useful to them in future decision making. They can communicate their understandings, ideas, and beliefs about science to others in meaningful ways.
6. Understand the nature of science and science concepts that are relevant and useful to their lives
Students have an appreciation of the changing nature of science and that its basis of science knowledge, science inquiry and science as a human endeavour will shift, grow and or change over time. With such changes, students will need to constantly reassess how their basic understanding of science concepts actually influences their changing world.
7. Accept a responsibility towards the natural environment
Students accept a care for God's creation. Students understand that their decisions and actions have consequences for the environment, both positive and negative.

Table 1.2. (Continued)

8. Understand science as being value-laden Students recognize that science is not wholly objective, but instead a human construction to explain our natural world and therefore laden with the values which different people bring to it. Accepted scientific views are a result of scientists reaching a consensus about science explanations. Similarly, students need to participate in informed debate about science explanations and their associated moral and ethical issues associated. Students need to appreciate why moral and ethical considerations are taken into account in such decision-making
9. Engage with science as accessible and do-able Students are intrinsically motivated to take on the challenges of science. They have an appreciation of science as do-able, achievable, and accessible to them. They have the skills to investigate interesting questions about their world.
10. See the potential for science to contribute to the common good Students see themselves as global citizens, and the potential role that science plays in contributing to the common good. Students are empowered to enrich the world with direction, meaning, purpose and hope.

Science Education as a Matter of Value

> Choice of curriculum content, depth of treatment, and emphasis, are matters of value; they cannot be resolved by empirical data. Once we have agreed on them, of course, we can then seek empirical evidence about which way (or ways) of teaching them are most effective. (Millar, 2008, p. 1)

In the messiness of arguing over definitions of scientific literacy, (a situation which has arguably hampered progress in science education), it may be important to note that the attempt to define scientific literacy is largely a philosophical argument; not scientific or educational. Questions such as: 'What outcomes do we want for our students in our communities?'; and, 'For whom are we teaching science?' are matters of value, not science. Answers to these questions are largely contextualised, and thus should be inherently different from each other. There is no expectation then that different groups, bodies, or organisations around the world should reach consensus on the definition of scientific literacy, as answers to these questions should differ according to the values of the organisations themselves. However, what seems to be a common thread among all definitions of scientific literacy is a focus on the capacity to use science within, or for, some sort of beneficial societal purpose. So, notwithstanding the contextual nature of scientific literacy, it seems that whichever way one defines it, scientific literacy invariably means more than just learning the science content.

Science for All

One of the prime functions of science in the industrial era was to produce new knowledge, and subsequently for science education to produce the scientists who would be the driving force of that knowledge production. After World War II, the need to

reindustrialise took focus forcing school curricular to adjust in order to meet the need for the increasing number of science graduates (Murdoch, 2006). Millar suggested that this focus has not changed - that most school science still looks as though it has been designed primarily to begin the training of the next generation of research scientists.

Dillon highlighted a concern in that science education could be seen as more often than not benefiting the minority of students who go on to become scientists at the cost of those who do not. Further to this, Millar suggested that science educators were faced with confronting a value propositions based on the question "Who you are teaching science for?" (Millar, 2008). If science education is for ALL students, then the associated type of curriculum and pedagogy should be markedly different from that associated with teaching science explicitly for those who become scientists.

The CEOM has positioned itself clearly in favour of a science education for all students. If the Archdiocese of Melbourne wants a science education for all students, whereby students will "see the potential for science to contribute to the common good", "engage with science as accessible and doable" and who can think critically about scientific issues as well as make good decisions for themselves and society, then the curriculum and pedagogy of teachers must change in order for this be evident in practice. But how does a system go about supporting teachers with change of this kind on a large scale?

PART 2: THE NATURE OF SYSTEM SUPPORT FOR SCIENTIFIC LITERACY

Focusing on School Factors in Professional Learning

Large-scale improvement in science learning and teaching across a sector of 350 schools is a difficult challenge. Historically, most efforts at this have involved large, "broad-brush", automated professional development (PD) programs which target as many teachers as possible to produce an overall "mass effect" on the sector. This approach might make sense at first sight; after all, there have been significant studies which find that teacher quality is the most important factor in student achievement. However, while the mass PD approach to sector-wide improvement may work on occasions in subjects such as literacy and numeracy, there are some fundamental differences in the way science education is enacted in a school (particularly at a primary level) which have the potential to negate the impact of teacher quality on improvement in science.

Firstly, science is not as compulsory within the curriculum as mathematics and literacy. There are no NAPLAN (National Assessment Program – Literacy and Numeracy) tests and little overt pressure from parents or governments for increased science in schools. Science is often seen as optional in many primary schools, or at the very most, given passing attention within the curriculum. Secondly, formal leadership within a school is not often a proactive enabler of science within the school. The message that this invariably sends to teachers is that science is not important and not worth professional time and energy. It may also make endeavours to improve science through partnerships or projects more difficult to initiate if teachers know

there will be little support when it comes to implementation. The nature of leadership support for science also tends to dictate how science is incorporated into the planning process and subsequently into the curriculum. It could be argued that it is difficult to show quality teaching in science when time and emphasis within curriculum planning is not supported.

The type and amount of resourcing within a school also impacts the abilities of teachers to demonstrate their teacher quality in science. Poorly resourced school efforts in science dampen teacher motivation for improvement. A lack of a culture of prominent science teaching, and associated poor profile and standing of science within a school can also inhibit the ability of teachers to operate at their genuine teacher standards. The combined affect of these factors means that sector attempts to improve teacher quality in science may have a reduced impact if they don't address these other whole-school factors. From a personal perspective through observation across many schools, I have seen teachers who have undergone what I would have argued was high quality professional learning, but certain school factors have persisted that have negated the anticipated outcomes from such professional learning experiences.

The upshot of this is that individual school factors need to be addressed equally, if not more, than teacher quality issues in science. If science is not on the school agenda, teacher quality in science will generally be quashed. These observations have prompted the CEOM to rethink approaches to scaling up professional learning for sector-wide improvement in science, particularly when considering the type of professional learning support required to genuinely enable the development of scientific literacy.

Taking a Different System Approach

Scientific literacy is a diffuse, complex idea open to wide interpretation. It has become increasingly clear to me that change in science education towards a scientific literacy approach is not going to be solved by a top-down PD program rolled-out for the masses. The development of scientific literacy in the ways I have outlined above requires deliberate and careful consideration on behalf of teachers, and as such, dedicated time and structures for reflection and spaces to experiment and play with ideas. In attempting to respond to the school factors which impact the effectiveness of teacher quality programs in schools, one recent action has been to approach the school as an entity in itself - a whole learning community. In so doing there is acknowledgement of the interrelatedness of all elements of schooling and the often fickle balance which resides within a dynamic and ever-changing system.

By paying attention to issues associated with the nature of teacher change – in particular the need for it to be supported of over long periods of time - the CEOM in collaboration with Monash University developed the Science Teaching and Learning (STaL) program. STaL was a five day, year-long professional learning program that specifically targeted learning and teaching in science. Our Lady of Good Counsel (OLGC) Deepdene had the foresight to send four teachers to the 2006 program, and multiple teachers to all programs since. STaL became the professional learning

which underpinned OLGC's work in scientific literacy. The STaL program had built-in time for reflection and discussion. A whole day was devoted at the end of the program for a process of reflection and writing in the form of cases (Shulman, 1992). Between-school visits were facilitated to maintain and develop participants' thinking. But above and beyond the content that was delivered, the program established the core values of teacher-led change, active teacher reflection, treating teachers as professionals, and a focus on relationships – all of which were to underpin all subsequent professional learning in science at the school.

OLGC's continued involvement in STaL combined with extra support from the CEOM and the Monash team created time for OLGC to implement and trial ideas at a whole-school level. Together, the CEOM and the Monash team supported the school to trial a whole-school, multi-domain approach to planning which built notions of scientific literacy, as well as time to trial and practise planned units in the classroom.

Allowing time for OLGC to think and talk and trial was one of the most important aspects of successful change at OLGC. In what could be an important lesson for other policy makers, interestingly, it took over four years before we saw outcomes of the kind usually sought by bureaucracies as measures of success. Allowing real time for deep and sustained change is rare among education bureaucracies because it goes against most bureaucratic system imperatives which insist on overt outcomes in short time periods, frequently in annual allotments. In the face of few major milestones and little physical change in teacher practice as viewed from the outside, those working closely with the school, which importantly included members of the CEOM and Monash, saw at close hand changes in teacher thinking, teacher language, teacher planning and eventually significant change in classroom practice.

Another important element of the nature of system support provided to OLGC was to allow teachers take charge of their own professional learning which led to a greater appreciation for, and value of, their professional knowledge. There was a deliberate "light-touch" approach from a system point of view and no pressure in terms of timeframes for success was imposed on the school. Instead surrounding the school with good people and funding to support autonomy in decision making, development directions and expected actions were essential so that the school maintained professional responsibility in driving its own change.

Creating conditions for teacher professional learning was crucial and that is difficult to achieve if teachers are not respected as professionals. During the STaL program teachers were supplied with overnight accommodation in first-rate hotels complete with dinner, breakfast, and social drinks in just the same was as occurs in most other professions. During the writing of this book, teachers were through writing workshops and dinners as well as weekend writing retreats in productive locations. In valuing and respecting teachers in this way the values of the system itself (CEOM) became explicit in terms of valuing individuals, valuing teachers as professionals, and respecting teachers as innovators and knowledge builders.

Another important element of system support for this project was the association with a University, more specifically, a University with a history of supporting teacher-led change (a University that cared about teachers and valued relationships enough

to seek to build their trust). In essence, co-operation and collaboration between an educational system and a University whose values about schooling and operation was an important feature of the overall process. The Monash team provided the academic rigour and profile that allowed a relationship to develop that focussed the nature of interactions rather than measureable, short term outcomes.

A final and vital element of system support for OLGC was in the provision of explicit structures for reflection. The use of a 'critical friend' within the project provided teachers with an ongoing stimulus for thinking differently about scientific literacy. The importance of a critical friend cannot be understated. It allowed teachers to develop their own understandings of that which matters in science education. The use of cases as a way of encouraging teachers to reflect on their practice also provided a structure for thinking differently about science teaching and learning. The writing of these cases by teachers at OLGC has been showcased through the subsequent STaL publications (see, Berry & Keast, 2009, 2010; Loughran & Berry, 2006, 2007, 2008).

Over time, the focus on the aforementioned whole-school factors bore fruit. Leadership support for science was strong and active, profile for science was high and embedded in everyday school-life, the standing of teachers in science was raised through their publications, an innovative centre for scientific literacy was built, and a whole-school planning approach around scientific literacy for students was established. Out of this mix came teacher-led, whole-school change, where teachers had ownership of their ideas, control over its direction, and clarity about what scientific literacy meant for them.

Indirect Scaling

As the expertise of teachers at OLGC increased and the school became advanced in its thinking and practice, the CEOM thought about how to scale up the model for other schools. In line with historical education efforts at scaling up, it would be a natural extension for the school to become a lighthouse school for others in the Diocese. But it became apparent that the inherent differences between schools, together with the contextual nature of scientific literacy, would make it difficult to simply transpose, or even suggest, the OLGC model to other schools.

So OLGC was left to grow and develop in its own time. Interestingly, what we are beginning to see is a more natural extension of expertise and knowledge out to other schools as teachers develop, grow and move to positions in other schools. The Principal who oversaw the start of the project moved to a nearby school and is embarking on a similar program of scientific literacy with his staff in a new context. The Deputy Principal recently gained his first principalship at another school and is taking his learnings to his new school. The mathematics coordinator has become the Deputy Principal at another school, the curriculum coordinator is working across a number of schools, staff have contributed to state, national and international conferences related to scientific literacy, and have published a whole school set of cases about science teaching and learning (Smith, 2007), a number of staff attended leadership programs in science education and produced video resources for other

schools, not to mention the production of this book for other schools, and so on. The outcomes are impressive indeed.

Thus instead of a system pushing a model for scientific literacy on to other schools, there are now numerous others embarking on change initiated by the schools themselves based on an informed position and created in response to their own context. A form of indirect scaling has occurred without system mandates that appear to have resulted in an effective spread of ideas and expertise.

CONCLUSION

The chapters that follow represent an emerging map of how, when and why participating teachers at OLGC found scientific literacy in their own way. Throughout each of the chapters there is a thread that ties together changes in teacher thinking, curriculum planning, classroom practice, and student learning. These learning features portrayed through these chapters are reflective of the sorts of outcomes commonly sought by educationalists in relation to notions of active participation in the 21st century. The chapters are also reflective of the values that the teachers, school and system have come to articulate and proudly display.

The experiences written about in this book indicate that these teachers found the idea of scientific literacy to be useful. But perhaps more importantly, it is clear that the phrase scientific literacy itself has actually provided a symbol for change and a banner under which both school and system have learnt to operate differently.

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Simon Lindsay is a Senior Project Officer for Science, Innovation and Research at the Catholic Education Office Melbourne (CEOM).

BRIAN GRACE

2. PAVING THE WAY FOR SCIENTIFIC LITERACY

OLGC IS A LEARNING COMMUNITY

Our Lady of Good Counsel (OLGC) is a learning community focused on developing the learning outcomes for each individual learner. Every staff member lives this through the school's vision statement of "Nurturing Mind Body and Soul".

I need to say from the outset in reflecting on the work that has gone into our Scientific Literacy project that, at OLGC, it was an expectation, not an option that each staff member was involved in professional learning that would not only develop them as an educator, but also improve their students' learning outcomes. That involvement in professional learning was an expectation that was always clearly expressed to potential staff at the interview stage by both the principal and myself (Deputy Principal). For some potential staff that expectation was too much and so they shied away from accepting a position at OLGC. However, for others the expectation was in full accord with that which they were seeking in their teaching career and therefore did not hesitate to accept a position at OLGC when it was offered. Clearly then, my view of the OLGC staff is one imbued with admiration for their willingness to continually develop themselves professionally.

With such a group of dedicated professional staff members eager to improve student learning outcomes, OLGC was involved in many projects. These projects ranged from the Enhancing Performance and Development Culture project through to the STaL project (which was run in conjunction with Monash University and the Catholic Education Office Melbourne).

In my role as Deputy Principal and more recently as Acting Principal I worked closely with both the leadership team (Principal, Deputy Principal, Head of Curriculum, Head of Student Services, Head of Junior School and Head of Senior school) and the staff, to ensure that whatever professional learning was undertaken would directly affect student outcomes. The question "How will this professional learning impact positively on student outcomes?", was a question that the staff or leadership team knew they would be asked when discussions about professional learning took place. This meant that all professional learning had a purpose and could be monitored and evaluated in the light of improving student learning outcomes.

At OLGC we felt we had a strong Multi Domain approach to teaching. We had the main ingredients of "key concepts", "throughlines" and planning that allowed students to "take action". However, despite these strategic directions, we still taught science separately; perhaps we were still too scared to teach science in other ways because of a lack of understanding. I say that because science was an area of the

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curriculum that the staff felt most uncomfortable teaching. We decided together that we needed to address the issue.

As a leadership team we strongly believed (from staff feedback) that it was time for us as educators to rethink what science meant for our students and also what that might mean for our teachers and their practice. In so doing, we needed to consider how we could support our teachers to address their existing perception of science so that they might be better able to provide learning experiences that would assist our students to develop the skills and thinking they would need for future learning.

The big question for us as leaders was "How do we support our teachers to ensure that science teaching and learning is meaningful while they at the same time also attempt to work within an already crowded Multi Domain curriculum?" These questions challenged us as leaders but they are also at the heart of the matter that leadership groups in schools everywhere need to be willing to explore, and be challenged by, if science education is to become an important and relevant aspect of contemporary learning in our schools.

SCIENCE: SO WHAT?

So why is science an important part of student learning? Well have you ever opened a newspaper and counted how many articles are related to science? Your initial reaction may be 'not many'. I also thought this but when I began to look more closely I was very surprised. I found that every day there were many stories which in some way related to science and that position science ideas as part of the world around us. While some stories do not initially appear to be specifically about science, on closer examination an enormous amount of science thinking is either embedded in the content of these articles or is required by the reader to be able to make sense of the information. To provide an example of my thinking, consider articles which recently outlined the collapse of a pedestrian bridge in New Delhi two weeks prior to the opening of the Commonwealth games. Those articles, as well as stating the obvious newsworthy items e.g., the number of workers injured, etc. also implicitly implied that the reader should be able to consider why the collapse happened.

Some of these articles suggested that there was a link between the weeks of heavy rain that occurred prior to the time of the collapse. So implicitly, the reader has to make sense of why heavy rainfall may have been a contributing factor to the event (collapse of the bridge). I wonder as you read my musings about these reports what ideas are now running through your mind? Are you drawing on some personal knowledge of science to help you develop a connection or make a link between the two events? Maybe you are thinking about the soil type or the type of foundations used in the bridge construction? Maybe you are considering types of building materials? Perhaps the rain pressured construction deadlines and in turn this impacted on the attention to detail undertaken in the building process. All of these possibilities are science based and demonstrate that the ideas in science need to be thought about and applied in order to be meaningful and useful.

Floods in Pakistan have also attracted much attention in the news. Once again there was the inevitable focus on loss of life and the human disaster which resulted,

but can the reader make connections between flood damage and the ongoing risks to human life which many articles suggested? Why do risks to health and well-being continue way beyond the actual event that caused the immediate devastation? Why is disease more likely to occur at these times and how does such heavy rain threaten food supplies?

For a reader to fully engage with these articles and the ideas contained within them, some understanding of science becomes important but equally, so is an understanding that science is interconnected with everyday life.

In my mind knowing and thinking about science provides a way of thinking about and engaging with the world around us. As a consequence, that means that as educators we need to support our students in developing and using this knowledge and thinking so that they can be engaged with and make sense of their world. It is that type of thinking that leads me to the view that we need to make science an important part of student learning. But what does that mean for how we approach the teaching of science?

RETHINKING SCIENCE AT OUR SCHOOL

At OLGC the leadership team shared an understanding (briefly outlined above) of science and began to discuss the classroom implications of these views in terms of science education. These discussions were strongly supported by the professional learning experiences that some members of leadership had undertaken. The Catholic Education Office Melbourne (CEOM) in partnership with Monash University had developed a professional learning program entitled Science Teaching and Learning (STaL), and this program became one of the main sources of inspiration and direction for rethinking science at our school.

Over a six year period OLGC committed an enormous amount of time and staff participation to the STaL program. Partly because the feedback from the first group of staff who participated indicated they felt more confident about their understanding of science concepts, and partly because of the way in which they discussed their experiences of STaL with other staff and the leadership team. As a consequence, the leadership team could not help but see the value in ensuring that all staff experience professional learning in the way it was structured and organised through STaL. The need was clear, the response was obvious.

The school's leadership made sure that the professional learning budget included sending staff to the STaL program each year. Science as part of a multi domain curriculum now had its own budget. Not just for equipment but ensuring it was integrated appropriately into our multi domain approach. It was obvious that the staff were embracing professional learning in science. Not attending the STaL program personally actually increased my ability to lead. This might sound strange but it made me listen more to staff, act on their feedback, and ensure appropriate support was given to them. The result was a committed staff that asked, "when is it my turn to attend STaL?" They wanted to be part of what was occurring in science. This was a total change from our earlier approach when we identified science as a point of concern in our curriculum.

From that time on, as a leadership team, we began to acknowledge the importance and benefit of reflection on our practice. Reflection was identified as not only important in the area of science but across the whole curriculum. This was also evident in the Enhancing a Performance and Development project in which we were also involved. As part of that project we provided opportunities for staff to receive feedback and then have time to reflect on that feedback and their practice. The leadership team felt this was important to individuals in helping them to develop their own practice.

Our thinking about science was shifting and as a consequence the school worked to promote more science teaching which in turn raised the profile of science in the school. More time was devoted to teaching science, more than ever teachers were talking about experiments and science activities; things were happening. Building on this, staff were encouraged to collaborate and to write about their experiences (see, Smith, 2007). That book captured their reflections about their science teaching experiences and helped to create even more interest and commitment to enhancing science teaching and learning at OLGC. Together, these steps were important in re-shaping how we approached our professional practice. Yet we were still not satisfied with how we were planning and teaching science. It still appeared to us as though it was a separate part of the teaching in each classroom. The content was not linked or intergraded into unit work and the teachers often only thought about science as experiments and wow activities (not dissimilar to that which Appleton (2002) described as 'activities that work').

We had to extend our journey further. We saw the need to take a further step into thinking about how to build on the learning that emerged from the writing experience. Our expectations for professional learning were continually realized as our learning experiences continued to impact our work in positive ways.

SCIENTIFIC LITERACY: WHAT DOES IT MEAN?

A new term began to emerge in our discussions 'scientific literacy' but we had no idea what it meant or if it had any place in our school. We were familiar with similar terms being bandied about by our politicians about proficiency in literacy, mathematical literacy and so on, but there was less talk about students being scientifically literate so it was a new idea to us – one that initially seemed another piece of academic jargon.

We were familiar with the notion that someone who is mathematically literate can participate in their world mathematically, that is they could walk into a shop with $10 and know how many items they could buy. Or they would know how long they needed to wait before the next train arrived at the station. Being mathematically literate supports being an independent person in the world and links with the idea of being an independent learner - someone who can take control of their own learning. As a leadership team, we thought if that was the case for mathematics then perhaps we should consider similar ways of thinking in terms of science - especially knowing that our students encountered so much science in their everyday world. We wanted the same skills and independence to be developed for our students in science. We wanted

our students to become scientifically literate. We wanted to see our students choose to read about science in their reading hour and to be able to discuss with their fellow classmates their views about the issues they were reading. We wanted our students to be reading and willing to identify local and international science issues and incorporate them into the "So what?" of their inquiry during their multi domain units.

With all of this in mind and the financial support and backing from the CEOM we decided that the first step for us all as educators was to rethink our perceptions of science. The leadership team felt that this meant we had to encourage teachers to move away from the more traditional primary school ways of thinking about and teaching science. We needed to change the prevailing perception that classroom science was all about experiments. We needed to start finding ways to link with the science that was all around us in our everyday world.

The world our students live in is more than just their local community, they have access to information from everywhere and that information is accessible from a variety of sources and available at almost any time. The world had become a global community. As educators we could see that accessing information was easy but we wondered whether our teaching helped or hindered students in determining the accuracy and validity of that information. How would they be able to decide how to use information to assist their decision making? What thinking, knowledge, communication, personal and interpersonal skills did they need to function in that way?

At both a leadership and staff level we began to see that perhaps as a school we were not developing the necessary skills as effectively as we could and that perhaps one way of doing that better was to utilise more meaningful contexts for learning.

CREATING THE CONDITIONS FOR CHANGE

The leadership team believed that the biggest influence on our students was teachers so we decided to concentrate more time, finances and opportunities in finding ways to support the development of teachers' practice in our own school context. We could see the need to work on raising awareness of our own practice and assist and find alternative ways to think about and attend to our teaching.

We employed a critical friend to support us in our planning meetings and to work with teams of teachers in asking questions and challenging our thinking about our planning and our practice. The critical friend was able to view multi domain planning and suggest/discuss with staff how to incorporate scientific literacy into their units of work. This support helped provide staff with the confidence they needed to own their professional decisions and to approach scientific literacy in new and innovative ways.

We provided time for teachers to talk and work together to share ideas and strategies and reflect on their work. We gave our teachers permission to take risks with their teaching and learning ideas in the classroom and we trusted them to make decisions that would be appropriate for their students' learning in their classroom contexts. What we very quickly started to see then was teachers engaged in professional discussions. Approaches to unit planning also started to change and we began to hear the term scientific literacy used more widely across the school.

WHAT IMPACT HAS SCIENTIFIC LITERACY HAD ON STAFF AND STUDENTS?

When you are so heavily involved in a project or new learning it can become easy to overlook growth and achievement. This seems to be particularly so when it comes to schools and change. Teachers are often harsh critics of themselves and each other. It is often not until they map their success or have seen their efforts highlighted and valued by others that they that they genuinely see and feel a sense of achievement – and that approach seems to pervade all levels of educational systems and bureaucracies.

Indicators of success are formulated in many ways. Some forms are helpful and others perhaps not so - especially noticeable when cause and effect is seen as a simple mathematical exercise (teacher says + student does = measureable outcome). The reality of teaching and learning is that it is a complex process with sometimes outcomes that are both expected and unexpected, but embedded in the day to day happenings of the classroom in ways that too easily go unnoticed. The pedagogical expertise that is brought to bear in helping students learn for understanding is evidence of knowledge, skill and expertise that often goes unrecognized and under-valued (Loughran, 2010).

One of the strongest indicators of success for us as a leadership team occurred at staff meeting in early 2010 when Professor John Loughran from Monash University asked to attend a staff meeting. We were discussing what we had been doing, and as was typical for us, we shared our ideas and concerns about our practice. John said something to the effect that, "The conversation currently taking place here does not happen in many schools and I don't think was happening in this school 3 years ago." His statement was telling for me because it was at that moment that I realised that everything we had invested so much time in as leaders was now bearing fruit; this was a measure of success that we could quite easily have overlooked. The type of recognition inherent in that experience is the type of thing that develops self-belief so crucial to ongoing success. It confirmed to us as leaders that we had been working towards something that was leading to positive change not just in terms of teacher thinking but more so, in the culture of learning at our school.

SCIENTIFIC LITERACY: WHERE ARE WE NOW?

Scientific literacy is defined in PISA as:

> ... an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the issues of science, as a reflective citizen. (OECD, 2006, p. 12)

There are many definitions of scientific literacy out there but the reason for choosing the one noted above is mainly for the last four words "as a reflective citizen". At OLGC these are the words we have come to value and these are the words which

drive our practice. These words emphasise for us the importance of wanting our students to be engaged in the science that is happening around them on a daily basis.

Currently the CEOM has released their 'Sacred Landscape' (CEOM, 2009) document which outlines their vision for contemporary learning. A component of their schema is engaging the learner in the contemporary world. What better way to do this than through scientific literacy? As discussed earlier in this chapter, scientific issues are part of our everyday world and if the learner is to "take action that matters" then what better way to achieve this than through a serious focus on developing scientific literacy. The journey to achieve that at OLGC has been challenging, not always easy but without doubt, exceptionally rewarding and that has been for a number of reasons around the types of things we have questioned and taken seriously in our reconsiderations of science teaching and learning.

Should science be a part of the primary school curriculum? Should experiments be a component of that science curriculum? Should schools have science rooms/ areas? The simple answer is yes. Science/science spaces in schools should be such that students are able to be immersed in different forms of thinking and learning about the world around them. It should be that children read about scientific events and investigate scientific ideas and use current technology to further develop their understandings, and should be able to do so in comfortable chairs not necessarily behind a bench with a goose neck tap and deep sink. Should science be held every Thursday afternoon between 2.00 pm and 3.30 pm? The simple answer no. Science should be part of a multi domain approach that truly supports curriculum development. In that way, scientific literacy can be a goal that will have real impact on student's learning. That would be a good measure of success.

Being a part of the Scientific Literacy project at OLGC has taught me much about leadership and the conditions required to support school based change as well as everything I have learnt about scientific literacy. I am firmly of the view that in undertaking any new project it is important for it to be supported by the school's leaders. That support means there needs to be a clear vision, a noticing (in the ways described by Mason, 2002) of the needs of teachers as they try new things and develop alternative approaches to practice. Above all it requires trust in teachers as the prime movers in enhancing learning, that is, a trust in the capacity of teachers as professionals. I have seen it work that way, the chapters in this book illustrate it for others to see and understand.

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Brian Grace was the Deputy Principal and then Acting Principal at OLGC throughout the Scientific Literacy Project. He has recently accepted an appointment at another school as Principal.

KATHY SMITH

3. LEARNING FROM TEACHER THINKING

An Insight into the Pedagogical Complexities of Scientific Literacy

Scientific literacy is a new consideration in the teaching of science and for teachers it raises many questions: what does scientific literacy mean particularly in terms of student learning?; How is it evident in the classroom?; and, Will it require changes to present planning, teaching and assessment practices? Many of these questions can only be answered by teachers themselves as they explore these issues in their practice. Yet the teacher's voice has been noticeably absent from the present debate about the merits of promoting scientific literacy as an outcome for students. This is regrettable because teachers have a significant contribution to share in terms of understanding and developing this new vision for science education.

The very nature of teacher expertise lies in the ability to shape meaningful student learning within a constantly changing, consistently complex and often ill-defined professional context. This is particularly true with science curriculum which has been reinterpreted by teachers, in particular primary teachers, in ways which enable them to access, think about and work with content to enhance student learning. This process is not only challenging but increasingly important for teachers when their personal confidence is continually compounded by an ever expanding and increasingly demanding science curriculum. Therefore working in the role of critical friend with the teachers from Our Lady of Good Counsel (OLGC) has been an exciting experience for me because this is a project which acknowledges and values teacher professional experience and the many important insights teacher professional knowledge offers about student learning.

Throughout this project I have had the privilege of encouraging the OLGC teachers to examine and share their thinking and their experiences as they explore new learning in science. I have worked closely with the teachers in ongoing meetings to plan the early stages of unit development, clarify the big ideas to be explored in each unit and develop the related understandings that will guide their teaching. During these meetings I have attempted to ask some difficult questions about planning and teaching and tried to ascertain each teacher's motives and reasoning for their professional decisions; particularly the knowledge they call on when they are faced with planning dilemmas: How do they decide what actions are the most appropriate?; How does working to promote scientific literacy influence these decisions?; What indicators do they use to determine if the implemented approach has the desired impact on student learning?; and, Have observations of student learning behaviours

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changed since the project began?, to list but a few. I listened to the many ways teachers connected this thinking to their selection of student learning experiences and how this thinking determined their judgments of progress.

We have taken time at the completion of each unit to reflect on the teaching and learning successes and to identify the areas that have emerged as problematic. We have shared our thinking, dissected our practice and stretched our professional expertise in an attempt to unravel some of the pedagogical complexities associated with constructing an understanding of scientific literacy in the classroom. In doing so, some important considerations have emerged in relation to teacher professional learning and pedagogy and I believe that these contribute new perspectives to the scientific literacy debate.

VALUING TEACHERS' PROFESSIONAL KNOWLEDGE

When the teachers at OLGC began to consider scientific literacy as an outcome for their students, it was amidst the everyday intensity of an already busy and demanding teaching role. The demands and time constraints were the same as those faced by many other teachers. However, these teachers were offered an additional type of support because the school leadership team made a point of noticing the busyness of their teaching routines and attempted to create some internal support structures that might provide time and assistance for them to think about their practice. The role of 'critical friend' and regular designated planning session times, where teachers worked in teams, were two of these support structures.

At OLGC these planning sessions were valued by the leadership team as an important opportunity to encourage teachers to notice and rethink the issues underpinning their practice. Teachers were released from their classroom teaching duties for two ninety minute sessions each term and were able to sit and work with me (critical friend), the school based Teaching and Learning Coordinator and other teachers who were working at the same grade level within the school.

These sessions were about finding ways to remind teachers to notice the possibilities and opportunities for alternative thinking and action within their regular classroom teaching routines. These meetings aimed to provide professional support so that teachers might be more likely to think about what scientific literacy meant, and as a consequence, notice opportunities in their teaching to consider the implications of these ideas; even if it meant finding alternative ways of working and thinking about their practice.

For most of the project I worked alongside the school's Teaching and Learning Coordinator and we discussed the challenges of preparing for, recording, recognizing and assessing teaching aimed at promoting scientific literacy. We listened to each other's personal reflections as well as those of the teachers and we observed first-hand the frustrations they experienced as they tried to rethink learning and the structures which traditionally defined their practice. Not only did these planning meetings provide an opportunity for teachers to participate in professional learning (from and with each other; sharing ideas and learning together), but they were also a powerful professional learning experience for each of us.

PROFESSIONAL LEARNING: SUPPORTING TEACHERS TO NOTICE

In an ideal world as professionals, we would notice and be aware of everything that is going on around us all the time as well as what we are thinking in the moment. However, the reality is, particularly in the classroom, that the pace of activity is intense and demanding so it is often hard for teachers to notice why and how they act in the way they do. To develop meaningful, personal professional practice requires an intense degree of self-awareness and noticing in order to make informed choices about to how to act in the moment, and how to respond to situations as they emerge (Mason, 2002). Even with the best intentions, noticing is not easy, and that difficulty is compounded when also trying to do something different.

As education professionals the teachers at OLGC constantly made deliberate decisions about how to respond to their students' needs in the classroom, yet because such thinking is fundamental to practice, they often didn't notice the nature of their decision making in action. To really understand the implications of developing scientific literacy as part of their classroom teaching, it was important that these decision making processes be made explicit and this required a level of self-awareness that was neither expected in their normal practice, nor particularly evident early in the project. Therefore, we decided that one of our roles (myself and Teaching and Learning Co-ordinator) in these planning meetings was to support teachers to recognize the rich range of possible actions and strategies they were developing and using in response to the new learning that was taking place. We needed them to articulate their thinking in order to access the pedagogic dilemmas they were managing in their classrooms. We therefore saw a need to encourage and 'give permission' for teachers to talk through, and actively respond to, the new and different learning opportunities they experienced as they emerged.

BUILDING TEACHER CONFIDENCE

To develop professional self-awareness requires trust and strong personal relationships. To establish these relationships we spent a great deal of time listening. Rarely did our voices dominate the planning sessions, we deliberately attempted to encourage teachers to talk and take ownership of the planning process rather than sitting passively and expecting to have their problems solved. Listening helped us notice that each teacher was different and that what each considered appropriate depended on what they valued which in turn affected what they noticed about their practice (Mason, 2002).

Listening allowed us to hear each individual teacher's priorities and use these to define some shared goals and understandings. We then tried to reiterate these priorities so that they were able to hear their own voice, recognize their own language and notice that their ideas were valued. In time they also came to notice aspects of their own practice in ways that enabled them to evaluate their actions against these goals.

The teachers constantly experienced frustration as they tried to change the ways they worked. This was at times uncomfortable to observe and it was often difficult for us to determine how best to respond or support them through these difficult times. Over the past two years we came to realize that although these frustrations were initially problematic they were also extremely valuable in terms of each teacher's

professional learning. Together we established a mutual understanding that our role was not to 'fix' these problems but instead to find ways to remind the teachers that the answers were most likely embedded within their own professional knowledge.

As our role developed, we came to a position that allowed us to give these teachers 'permission' to work with their thinking and their ideas and to provide the time and space for each to explore their preferred approach, explain their thinking and share their experiences. This meant building teachers' confidence in ways which encouraged them to share openly and professionally in searching conversations about teaching and learning. Although at times robust and sometimes uncomfortable these conversations always aimed to improve the teaching and learning of science and tried to define more clearly what scientific literacy offered students in terms of their learning and their future.

Over time teachers began to understand that we trusted them and had faith in their capacity to make appropriate decisions about their practice in their classrooms. In turn, they trusted us and were willing to talk and share their ideas and concerns without fear of criticism or judgment.

THE ACT OF LISTENING TO NOTICE

My experiences and observations as critical friend have reinforced for me the belief that powerful professional learning resides within teacher conversations. However, in my role, listening to words was not enough. Listening had to be about noticing the professional thinking which underpinned the words or expressions teachers used when they shared their stories. This noticing became the most important skill in facilitating teacher professional learning in these planning sessions because often the most powerful and enabling opportunities for these teachers to rethink their practice were embedded within their own conversations, hidden amongst the 'noise' of the talk that surrounded planning and classroom management. Within these conversations there were moments in which it was possible to hear beliefs about scientific literacy that were driving each teacher's practice, what that meant in terms of what they valued in their teaching as well as their vision for meaningful learning.

Sometimes this thinking materialized as tensions which arose in decision making. These were the times when teachers became frustrated and talked about being stuck or lost, or when they said they didn't know what to do next. At these times they experienced difficulties as they attempted to draw on the wisdom encapsulated in their collections of professional responses, their repertoires of options, which they had developed over time and which formed the basis of their professional expertise. In the past these options had reliably guided their decision making but now the existing repertoires appeared inadequate because in some way they had started to see science education differently; they had started to rethink what meaningful learning looked like and the nature of the conditions that they now saw as necessary for enhancing such learning.

Across the project a new framework for learning began to emerge. In time that framework created new concerns about practices and approaches that had previously not been noticed or simply overlooked. Their new thinking challenged each to change the ways in which they worked and that in turn led to changes in the ways their

students worked. With a new frame of reference the previous indicators of student learning, which were familiar, were not always so noticeable. Instead, a number of new and unanticipated events began to replace that which once was. Initially, those events, although informative, in the chaos of the moment were not immediately noticed and the potential of these unexpected events therefore were not so readily recognized. At these times, to facilitate professional learning, together (myself as critical friend and my colleague the Teaching and Learning Coordinator) we worked harder to listen, notice and assist all of our teachers to notice, recognize and attend to these new events.

AN EMERGING FRAMEWORK FOR LEARNING: THINKING DIFFERENTLY ABOUT UNIT PLANNING

A very powerful example of this new thinking occurred in the first year of the project and in time led to some significant changes in the ways teachers began to think about and implement their actions in relation to unit planning. In a level planning meeting with teachers from the grade three area, one teacher expressed dissatisfaction with the time that she was able to devote to one particular unit of work. Her comments drew attention to some very interesting obstacles for learning and raised an issue that teachers had subconsciously accommodated for some time in their practice. However, now it was more significant because they were all actively rethinking the type of conditions which would effectively contribute to promoting scientific literacy as an outcome for student learning – what they noticed and why was clearly changing:

> *Teacher 1: It is such a shame that we have to close this unit* (Topic: *'Relationships'*) *and move on to the next. The children were just really beginning to enjoy this topic but Term 1 is nearly finished and we have to start the new unit next term. (Field notes from meeting)*

In this meeting I heard what these teachers were saying about moving on to a new unit; the regular routines, the term structures and compliance with an accepted planning routine. However, I listened instead to the tension that was underpinning these comments. It was a tension about time constraints and the impact these had on learning. There appeared to be some discrepancy between what teachers said they valued, that is the importance of providing time for learning, and what they were actually doing; imposing definite time constraints on how and when students engaged in learning experiences.

It was only when the teachers at OLGC started to consider scientific literacy as an outcome for their students that this approach to planning became problematic for them. Their planning practice was typical of the accepted approach in most primary schools in which teachers traditionally plan inquiry based units of work which attempt to meaningfully integrate a number of curriculum areas in the hope of encouraging students to draw on a range of skills and understandings. These units were taught and developed across a school term (on an average ten week time block). At the end of each term the unit concludes and preparations begin for introducing a new unit the following term. The new unit is often totally unrelated in terms of content and knowledge to the previous unit. However, as indicated in the above transcript,

these teachers had changed some of their approaches in the classroom and were beginning to see a different level of student engagement taking place. As a result the idea of finishing a unit and abandoning the potential learning now presented a new challenge; a challenge not so readily recognized in the past.

As teachers started to develop personal beliefs about scientific literacy, that is what they valued in their teaching and their vision for meaningful learning, they became increasingly concerned that their existing planning and teaching practices might actually be contributing to 'disconnected' student learning. They were beginning to question whether their students were leaving their thinking and ideas behind as they moved on to new units; never really exploring the potential of their ideas and thinking in a unit as they were pushed towards a different topic. I noticed that these teachers appeared to be voicing a view that student motivation and interest was being sacrificed at the expense of 'getting through' the curriculum; this again was now becoming problematic. However, this tension created new possibilities for planning.

EMERGING NEW IDEAS

> *My main concern from this meeting was the view expressed that time was working against effective teaching of this unit and that the work that was started would now be left behind when heading into the next unit. This got me thinking about how it might be possible to see if the year's units might all link together in terms of the understandings embedded in each. I decided to play with this idea in an attempt to visually represent how the teaching of one unit could effectively contribute to the understandings developed in another unit. (Field notes from meeting)*

After this meeting I went away and developed the ideas displayed in Figure 3.1.

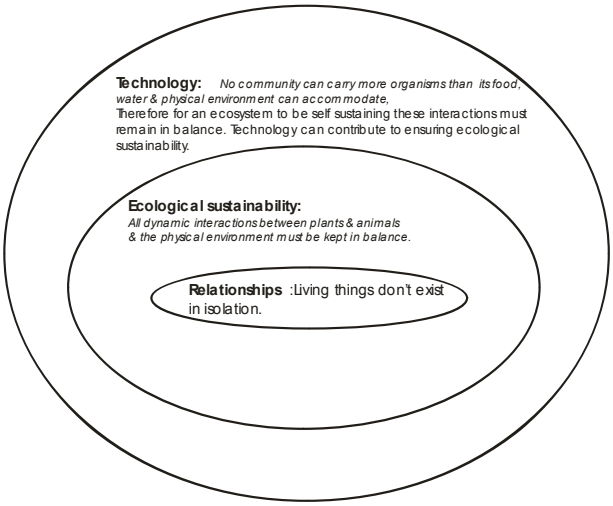

Figure 3.1. Interconnections of planning across topics for the year.

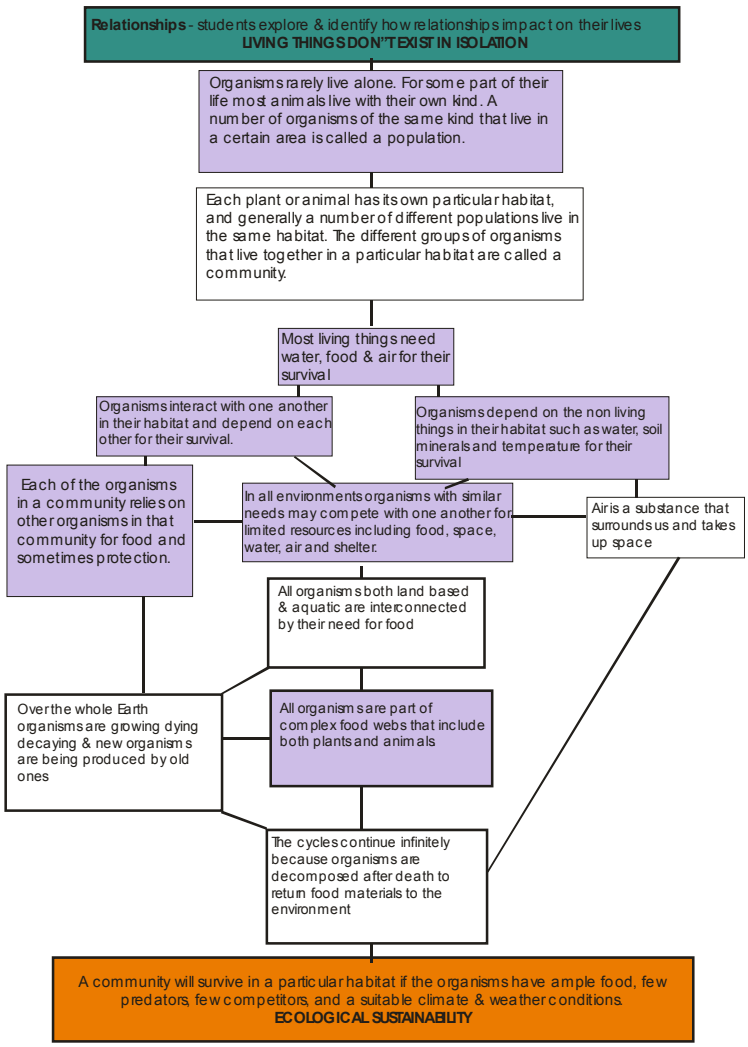

Figure 3.2. Relationships and ecological sustainability (Adapted from DEECD, 2006).

By developing this diagram in my field notes I was trying to conceptualise an alternative way of thinking about planning which might enable teachers to see that they had options, that it was possible to think differently about their planning and teaching routines.

I began to explore the idea that perhaps the unit at the beginning of the year, in this case 'Relationships', introduced ideas and thinking that had the potential to flow out to the following units across the year, that is 'Ecological Sustainability' and

'Technology'. As this thinking represented a very alternative approach, I decided that it might be useful to represent these ideas visually. The diagram (Figure 3.1) became a way of explaining this approach as a ripple effect for learning, just as in a pool where a stone is thrown in the middle and the waves radiate out from the centre. So too learning could start and potentially develop more broadly.

The idea of linking units seemed to offer a useful alternative framework from existing planning structures but it required very clear statements outlining the big ideas of each unit. I was of the view that once this information was clarified it might be possible to consider if there were links across the ideas. Exploring the possibility of how the big ideas of each unit might link together in some way was an important way of ensuring that students' learning stayed alive; that they valued what they learnt and did not see their thinking connected or limited to only one unit.

The challenge of exploring possible connections across topics was compounded by the need to work on different understandings for different grade levels within the school, i.e., deciding what was age appropriate and also what was of interest to the students at each level. This required some brainstorming of possible ideas and again I continued to explore resources and ideas to determine possible connections and tried to represent these in some visual way (see Figure 3.2, 'Relationships & Ecological sustainability').

MAINTAINING TEACHER OWNERSHIP

I presented my thinking and diagrams to the staff and we engaged in discussions about the strength and weakness of this approach and the inevitable challenges which were likely to emerge. The diagrams not only showed that we had some new options for planning but also highlighted the limitations of our present planning routines. The feedback was interesting with some teachers seeing immediately the value of keeping student learning alive in this way while others were hesitant.

Even though many teachers could see the merit in these ideas the immediate shift in thinking was too great and too challenging to implement immediately. It was important that the ideas be seen as possible options not as solutions, and most importantly, ownership and decisions about how to move forward had to reside with the teachers themselves. It was not something to be imposed by others.

For some time unit planning continued in the familiar ways but it was becoming increasingly obvious that teachers were seeing inadequacies with that planning approach. They commented that they felt they were not only leaving student learning behind at the end of each unit but that they were also planning too much content and did not have sufficient time to support students to really develop a depth of understanding. Another concern evolved around thinking skills.

It became apparent that in each unit there was not enough time for students to practice and develop the range of thinking skills that teachers were beginning to value as a fundamental aspect of scientific literacy. Teachers were voicing concerns that scientific literacy required each student to develop a particular type of critical thinking and they were seeing the need for teaching and learning experiences that worked towards ensuring that aspects of that thinking be continually practiced, developed

and refined. Students' thinking then needed to be seen as something that habitually recurred so that for each student it was intrinsically embedded in their way of seeing the world. This type of thinking needed to be at the heart of the nature of the learner no matter what the content or the context of the learning. Disconnecting the learning between units was now increasingly being seen as disconnecting the development of this approach to thinking.

Finding common learning and ideas across units began to be seen as a new opportunity for teachers. It was a way of ensuring that opportunities were provided to develop a depth of learning while also developing students' critical thinking skills. We observed that teachers were attempting to find ways and strategies for revisiting experiences from past units.

What we saw happen overtime was a gradual yet decisive move by these teachers towards linking units. How they went about this differed for each level but knowing that they had 'permission' to explore this idea was extremely important. Eventually teachers were initiating more conversations about planning for linking until eventually, in their teams, they were discussing planning with the whole year in mind rather than attending to separate unit titles. This approach required them to consider all the selected unit topics across a year as one body of work, and to identify the key understandings for each and how these understandings could be mapped as interrelated connections across all units. This was a dramatic change to the traditional approach to planning.

Planning began to focus on creating conditions through which it was more likely that students would revisit and rethink their previous experiences in light of new information and key concepts. This view of ongoing learning fundamentally differed to previous well-accepted planning practices in primary schools. The change was in essence in response to the question: "How will you keep the learning alive?" That question became a very powerful way of challenging teacher thinking in relation to finding new planning practices.

SHARED UNDERSTANDINGS: THE RELATIONSHIP BETWEEN PROFESSIONAL LEARNING AND PEDAGOGY

'Action' was a phrase that teachers used repeatedly in these planning sessions, initially it was a term used to refer to a product at the end of a unit of work. However, over time we noticed that the use and intended meaning of the word subtly changed. A focus of our work centered on encouraging teachers to articulate what they meant by the place and purpose of action in unit planning. They discussed how action could be: a product; a type of thinking; a process of developing understanding; an opportunity for students to use and apply their learning in practical ways; and, an opportunity for both teachers and students to forge relationships with expertise beyond the classroom, enhancing the range of learning experiences students could access.

These ideas about action also represented to us the type of professional thinking in which these teachers were engaged. Their thinking was purposeful, it was aimed at understanding, and it was directed toward building very powerful professional relationships. The ideas they were sharing were exciting and innovative and some

strong shared understandings emerged in relation to planning and pedagogy. Through feedback, these were the areas teachers themselves identified that required fundamental changes in order for them to promote scientific literacy as a learning outcome for their students. Within these areas a number of fundamental actions emerged which guided what these teachers actually did in their classrooms. For example, planning* included:

- taking ownership of and feeling empowered to shape models of inquiry planning to meet specific teaching needs;
- confronting personal ideas and beliefs about science;
- recognizing and attending to the big ideas of science;
- recognizing and building on student input;
- providing sequential learning experiences particularly in terms of linking the learning across units;
- taking simple ideas but providing a depth of learning; and,
- finding links in learning to community and taking action in meaningful ways.

Aspects of pedagogy* that were seen as important included:

- clarity of purpose in teaching;
- responding to students learning needs and interests;
- promoting rich questions from students;
- accessing and effectively using a variety of contemporary resources and experts;
- promoting student thinking, curiosity and imagination; and,
- engaging students in meaningful contexts for learning. (*All derived from teacher feedback sheets)

Overtime the teachers clarified a new purpose for science teaching and my observations confirmed for me that the process of promoting student learning was now more engaging and also increasingly recognized by all as more complex. These teachers confronted their existing understandings, perceptions and beliefs about science and considered how they might shape the type of learning experiences they created for their students.

As these teachers worked through this process they developed some interesting alternative perceptions about planning units and the types of learning experiences which they now value but once were not identifiable on the pedagogical horizon. These new ideas, at times were challenging and risky, yet overall yielded some impressive examples of meaningful student learning and have been more than enough to inspire them to continue the pursuit for the development of scientific literacy in their classrooms.

SCIENTIFIC LITERACY: WHAT HAVE WE LEARNED?

> The mark of an expert is that they are sensitized to notice things which novices overlook. They have finer discernment. They make things look easy, because they have a refined sensitivity to professional situations and a rich collection of responses on which to draw. Among other things, experts are aware of their actions in ways that the novice is not, whether teaching, researching, attending meetings, administering, supporting colleagues, or preparing for any of these. (Mason, 2002, p. 1.)

This project has not only introduced the voice of the primary school teacher into the scientific literacy debate but has also recognized that when provided with appropriate assistance and time, teachers most certainly have the capacity to notice their actions and use their professional thinking to reshape and redefine the purpose of science education within their given context. This is a slow process and relies on recognition of their ability to make informed and appropriate professional decisions about meaningful teaching and learning.

I have noticed how these OLGC teachers' teaching for scientific literacy is far more than teaching science as typically outlined in curriculum documents; it is more than linking learning to everyday events or using contemporary technology to simulate and explore science concepts. Scientific literacy is about a holistic approach to teaching, it is about developing the whole person, it is about nurturing in each student a noticing of life and natural phenomena. Scientific literacy is about fostering curiosity, a willingness to question and an intrinsic need to seek understanding.

Teaching for scientific literacy requires careful, flexible planning, bringing together knowledge of the subject and knowledge of the learner to create a learning environment that builds student interests and explores the learning potential of contemporary events and issues. For the OLGC teachers, accessing, experiencing and talking about science ideas is no longer enough in their teaching. These teachers in different ways and to differing degrees have gone further and shared intellectual control with their students (see Mitchell & Mitchell, 1997 for a full description) and empowered them to make decisions, form their own opinions and apply their understandings in ways that are meaningful to their context and areas of personal interest.

The observations I made and the experiences I have had the privilege to share at OLGC have shaped my understanding of the type of professional support needed by primary teachers as they work through the practical challenges and dilemmas of attempting to rethink and reshape the purpose and meaning of primary school science. It has been my pleasure to work with and learn from the professional thinking and expertise of this committed and determined group of teachers. I am of the view that we as educators must begin to listen and notice teachers' thinking because we have much to learn from them; not only about what scientific literacy means but also the pedagogical complexities associated with implementing this alternative vision for science education.

From working with the teachers at OLGC and from reflecting and trying to make sense of all the experiences we have shared together, I am now able to conceptualize and articulate my personal understanding of scientific literacy, and just like the teachers with whom I have worked, I have started to notice how this now frames my thinking and my actions regarding science teaching and learning.

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Kathy Smith works as an Education Consultant undertaking various roles including Science Resource Officer with the Catholic Education Office Melbourne, project work with the Faculty of Education at Monash University, and school based consultancy in science education. As a qualified and experienced primary teacher, her interests and commitment are firmly based in primary science education with a particular interest in teacher thinking and pedagogy.

SECTION 2:
TEACHING FOR SCIENTIFIC LITERACY

CATHY DIMITRAKOPOULOS

4. WEARING THE DOUBLE L PLATES

Lead Learner

TO LEAD

How do you begin to define what it means 'to lead'? Well, to start, let's take a look at what the Dictionary says:

> To walk, drive, fly, sail, etc. in front of a group of people.

No, not for me.

> To take or pull a person or animal somewhere by holding onto them or something fastened to them.

Well … sometimes, but no.

> To be the most successful, popular, or advanced of all the people, groups, organizations etc involved in a particular activity.

Hey, you forgot best looking and most charming! BIG NO!

> To be in control of an organization, group of people or activity.

Define 'in control'.

> To cause someone to do something.

Too 'dictatorish' for me. I think that I like this one:

> To show someone the way to a place by going there with them[1]

Except, in our journey in scientific literacy, where is the place? What is that destination? Even though I can't clearly articulate the answer to this question, I like the idea of going there, with them (our staff).

TO LEARN

So many expressions and phrases are said 'off the cuff' about learning. Here's some that I've heard and what I make of them:

You live and learn.	*I learn to live. I live to learn.*
You learn the hard way.	*I learn the way that best suits me.*
You learn your lesson.	*That's right, your lesson – not the one someone sets out for you.*

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 39–46.

You learn from your mistakes.	*I think that you learn more from your successes.*
You learn the ropes.	*Only with scaffolding, support, trust and practice.*

Back to the dictionary to find out the meaning of, to learn:

> To gain knowledge or experience of something, to behave or think in a particular way.
>
> To improve your knowledge as a result of gaining greater experience or knowledge of something.

So I am a learner. I am learning something. What am I learning in this project? What/ Who am I leading?

MY ROLE IN THIS PROJECT

I have worked at Our Lady of Good Counsel (OLGC) Primary School for a number of years and in a number of roles. My particular area of interest has been curriculum development and I have always been part of different curriculum teams and the school's leadership team. Five years ago, as a member of the school's 'Integrated Studies' team, I attended a Professional Learning program – Science Teaching and Learning (STaL), run by the Catholic Education Office in conjunction with Monash University. Little did I know that in a few years, this experience would affect our school's approach to learning and teaching and our thinking about Science Education.

Following that experience, my role as Curriculum Coordinator evolved to eventually be titled, Head of Learning and Teaching. During this time, a new state curriculum (Victorian Essential Learning Standards - VELS) was being trialled and as a school, we took stock of our current pedagogical structures and practice and made the decision to implement change.

Our first major change was to move away from a two year 'Scope and Sequence' chart that outlined topics to be studied that were aligned to particular curriculum areas. We tried to define what a learner looked like in our setting and what experiences we valued for our learners. Using this data, we developed eight Key Concepts that would allow for connections across curriculum areas and would enable students to develop deeper understandings of the ideas that were being explored. As part of this change, the title of our teaching and learning shifted from 'Integrated Studies' to 'Multi-Domain'.

Throughout this process of change, the school made a strategic decision to continually send staff members to attend the STaL program. Recognising the school's commitment to Science Education, the Catholic Education Office was keen to support where they could and it was from these beginnings that the OLGC Scientific Literacy Project developed. The structure of the Project was a work in progress until it took its current form when I returned from maternity leave last year. At this point, I met

with the project's 'critical friend' to plan learning and teaching sequences with each level, twice a term.

But then a whole lot more began to happen …

A LEAD LEARNER VERSUS A LEADER

My role in OLGC's Scientific Literacy project has been unique. My experiences have been exciting, frightening, challenging and rewarding all at the same time. I have been pushed to explore my skills as a leader and as a learner and to reconsider what it means to be a leader. My involvement in this project has made me think about whether the terms Lead Learner and Leader are synonyms or antonyms.

My role as Head of Learning and Teaching has enabled me to work in a very productive and engaging relationship with our project's critical friend. Through our planning sessions with teaching teams, I have always tried to attend to the systemic requirements (VELS) which are organised into 3 strands: (i) Physical, Personal and Social Learning; (ii) Discipline Based Learning; and, (iii) Interdisciplinary Learning. Each strand is divided into several Domains (see Table 4.1 below).

Table 4.1. Victorian essential learning standards

Victorian Essential Learning Standards (VELS)		
Physical, personal and social learning	*Discipline-based learning*	*Interdisciplinary learning*
Health and Physical Education Interpersonal Learning Personal Learning Civics and Citizenship	The Arts Science The Humanities: History, Geography, Economics LOTE English Mathematics	Communication Design, Creativity and Technology Thinking Processes Information and Communications Technology

Our school uses an Inquiry Approach to implement the curriculum. The Inquiry Approach is based on a constructivist approach to learning and teaching whereby learners are equipped to construct and deepen their own understandings of the concepts being presented. Learning and teaching is organized through eight key concepts that are explored across two years. (These concepts and the years in which they are introduced are shown in Table 4.2 below.)

In developing our approach, our critical friend has challenged teachers to maintain links across our school's key concepts with the science in our world. She has prompted teachers to make science learning opportunities visible, authentic and engaging for learners.

Along the way, however, our project has developed into more than just the development of a new curriculum document. It has given teachers and learners a voice in curriculum planning and delivery, it has led us to reconsider our definitions and beliefs not only about scientific literacy, but also pedagogy in general, and it has challenged our views of leadership and the role of leaders.

Table 4.2. Inquiry approach key concepts

	TERM 1	*TERM 2*	*TERM 3*	*TERM 4*
Odd Year	***Identity and Diversity*** Students develop an awareness of their own identity and the diversity of others within the world they live	***Change*** Students develop an understanding that change is part of our lives and it impacts on the way we live.	***Communication*** We are all different and we express ourselves through a variety of mediums. Communication is continually changing. It impacts on and meets the demands of society.	***Wellbeing*** We have a responsibility to ourselves, those who care for us and our community, to nurture our mind, body and soul so that we can be the best that we can be.
Even Year	***Relationships*** Students explore and identify how relationships impact on their lives.	***Sustainability*** There must be a commitment to sustainability. We have a responsibility to future generations to protect and enhance the world we live in.	***Technology*** Students will discover that developments in Technology impact on, and will continue to change the world in which they live.	***Safety*** Students develop an awareness of and responsibility for their personal safety and the safety of those around them.

So what has changed for me? Mainly it has been my thinking and my actions in a number of key areas related to how I think about leadership, what it means to be a leader, and in developing an environment that can support staff learning and build good relationships.

LEADERSHIP: FREEDOM OR CONTROL?

I think that the word leader comes with lots of assumptions. Having the title of leader implies that you are in control and that you possess all of the answers. I have come to understand that for me, being a leader is not about control, it is about providing the freedom for others to discuss and share ideas, freedom to believe in oneself as a professional and the freedom to believe in and value professional practice, knowledge and expertise. This freedom has proven to be so important, time and time again, when working with teams of teachers. The answers we seek are not always easily defined, and they can be hard to uncover. For this reason, I prefer to think of myself as a 'lead learner'. It suggests that I am learning how to lead a willingness to learn, and a new way of thinking about what we do as teachers. I know that I do not have all of the answers - and that I cannot expect to, but that I am prepared to persist and grapple with ideas and thinking.

From the outset, the intent of this project was to allow teachers to construct workable definitions of scientific literacy. It was also about teachers finding their

voice and deciphering what this term would look like for them, in their classrooms and in their practice. With this in mind, my style of leadership had to be such that I could foster certain types of behaviour and interactions in planning sessions. It was crucial that teachers had the freedom to talk, share ideas, try something new, take a risk and be open to giving and receiving feedback. If I had all of the answers (which I didn't, anyway) and I was the only voice to be heard, not only would this have been inappropriate given the project aims, but would have stifled the growth and development of the teachers and the project itself.

MY LEADING AND MY LEARNING IN THIS PROJECT

Through my experiences of the project, I have learnt a lot about curriculum and scientific literacy as an outcome for students. However, most of my learning has been about leading. The greatest challenge for me as a leader at our school has been in developing my leadership skills. No-one teaches you how to lead, you are left to your own devices and you are entrusted to get a job done. There are numerous management tasks, jobs to tick off checklists, accountability statements and the like, but for me the real challenge is in 'leading', not 'doing'. For example, how do you effectively shift people's thinking from one place to another, to encourage them to challenge themselves and make changes within their practice? This is an emotive task that is fluid and changing. As a leader, you can experience success and frustration in the same moment. It requires patience to wait and listen, and determination to follow your beliefs even if at times this is harder than just giving everyone what they think they need. There were days when it all felt too difficult; I was being challenged left, right and centre. I began to think that perhaps I was not good enough for the job. For instance, the following conversation happened one afternoon in the staffroom:

> Teacher A: My class has had enough learning about animals, they want to learn about other stuff. All that we seem to do is Science.
>
> Me: And why can't they do other things?
>
> Teacher A: Because that's what we had planned. I'm following the planner.
>
> Me: Do you value what your learners are telling you?
>
> Teacher A: Of course I do.
>
> Me: So what could you do about it?
>
> Silence.
>
> Silence.
>
> Silence.

At the same time, these difficult moments were counteracted by many small glimpses of success, recognition and praise along the way.

> Teacher B: We should actually be asking the children what they want to learn about and going with it.

Teacher A: So we can actually change what we had planned?

Teacher C: Of course we can! I think that 'the two Caths' trust us enough to do the right thing.

I read lots about leadership. I sat back and I modeled aspects of my own leadership on others who I admired. My involvement in two leadership projects facilitated by the Catholic Education Office enabled me to explore modes of leadership and the impact of various leadership styles. These projects, Leadership for Contemporary Learning and Leading Science in Schools, opened my eyes to the complexities around leading groups of people. My reading has been focused around the work of Michael Fullan, William Bridges and John Evans. CARE, an acronym from that work has helped shaped my approach to leadership:

- **C**ommunication
- **A**pproachability
- **R**eliability (and I add mutual Respect here)
- **E**mpathy

THE PLANNING SESSIONS = THE FORUM FOR LEARNING

The structure and funding of the science literacy project at our school enabled the critical friend and I to meet with teams of teachers in VELS levels to plan twice a term. These sessions prompted rich, vibrant discussion, provided a forum for shared issues in learning and teaching, as well as an initiation into the Project for new staff members. Our goal in these sessions was to engage teachers in dialogue that would deepen and challenge their own understanding of the concept and to build scientific literacy into this discussion.

We also dedicated one of these planning sessions to introducing the idea of reflection. It took time to establish, as we needed to build teachers' confidence to openly critique their practice, celebrate successes and make changes for future learning and teaching. Through our efforts, we developed two reflection tools to guide our discussions, based on a document from the Catholic Education Office Melbourne, Learning Centred Schools: Sacred Landscape. These tools took the form of a PMI (Positives, Minuses, Interesting/Improvements) and a proforma in which teachers could consider various aspects of their pedagogy. It was in these sessions and on reflection about them with the critical friend that a great deal of my learning took place.

I believe that teachers initially came to these sessions thinking that they would leave with a nice and tidy unit to go away and teach and that the critical friend and I would 'tell' them what to do and how to do it. However, this was not the case, regardless of how tempting it was at times!

Teacher A: So what are we actually going to teach? I need to know what I'm doing!

Some grade levels came along to sessions with their planners already filled in for the term's work ahead. One small question from me challenged thinking a great

deal – 'Why?' What did filling in a planner prior to ascertaining student thinking and needs say about the learner's role in the learning process? It was from these kinds of experiences that I could see a shift in our staff beginning to occur.

The same situation occurred with certain concepts being locked in to particular Domains – for example, that 'Relationships' was a SOSE (Studies of Society and Environment) topic. I watched intently as our critical friend challenged teams to think outside these pre-conceived ideas and see the Science in what they were doing. It was fascinating and a powerful learning experience for me!

We watched as some teams struggled with communication and encouraging all voices to be heard. We observed the panic set in as some of them realized that they hadn't covered as many of the VELS domains as they wished to have.

> Teacher D: Well, it's June, and we've realized that we actually didn't cover enough Science as we focused too heavily on Immigration and Civics and Citizenship.

It was like sitting in a grand stand, watching your favourite team play, biting your nails nervously. We allowed the discussions and the frustrations to take place, and slowly, ever so slowly, clarity began to set in, like a little ray of sunshine after lots and lots of rain. These moments made me smile.

> Teacher D: We need to look more broadly at the curriculum. But that's what you've been telling us all along, isn't it? We just had to live it for ourselves, I guess.

The key to allowing all of this to happen was in creating the conditions for it to happen.

BUILDING RELATIONSHIPS

> [Leadership] involves the capacity to lead change and to develop others so that there is a critical mass of people working together to establish new ways. (Fullan, 2004, p. 15)

Our school's critical friend and I worked hard in developing productive relationships with the staff and the school teams. We were challenging an aspect of their lives that they were so passionate about and so dedicated to – their ways of teaching and learning. We had to create a culture in which teams could openly discuss their challenges, questions and of course, successes. In doing so, we were saying, 'we trust you and value what you think'. We walked alongside them in all of this. At times we stepped back, letting others learn and lead. And they rarely let us down. I came to see my confidence growing about being asked a curly question, because I knew that as a team, we'd come up with an answer. I watched, I listened and I learnt as our critical friend continually asked the teams, 'Why?' I was amazed by the questions that she posed for teams and the ways in which she stimulated their thinking. These are skills that I hope to further develop in my own leadership approach.

At a recent staff meeting, our critical friend suggested providing opportunities for teachers to share their stories and experiences about different aspects of the Project.

The level of enthusiasm and engagement from both presenters and participants was high and it confirmed for me the importance of relationships, trust and letting others learn and lead. I felt so proud of our staff that afternoon and of our school. I feel very privileged to have been a 'lead learner' in our journey in scientific literacy.

> The growth and development of people is the highest calling of leadership (Harvey S. Firestone)

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Cathy Dimitrakopoulos is the Head of Teaching and Learning at OLGC.

NOTES

[1] www.macmillandictionary.com/dictionary/british/lead

MARY HOWARD

5. YOU DON'T HAVE TO HAVE ALL THE ANSWERS

I used to think successful science teaching was knowing all the answers to Science questions and transferring what I knew to students. That was how I had learnt science in secondary school and on what I based my knowledge.

My teacher education program had not focused on science and as a young teacher I had not had the opportunity for Science Teaching Professional Development. But in 2005 when Monash University held their first Science Teaching and Learning Course (STaL) I decided to take up the challenge.

Now, if you asked me what has had the greatest impact on my teaching and hopefully my student's learning in the last 20 years I would have to say the STaL Project at Monash University. It wasn't so much the speakers I heard or the dialogue I engaged in or even the concepts and strategies that I studied. It was an awakening in me. An urgency to engage my students in the things they were interested in, and the necessity to stimulate today's students to think about tomorrow.

I didn't always understand the concepts of science myself but STaL helped me realize that *you don't have to have all the answers.*

SEEING THINGS DIFFERENTLY

I had been teaching for 40 years and fortunately was still welcoming change for the better in the curriculum. I reflected on change as it happened, tried not to throw the baby out with the bath water every time some new approach was hailed as the 'current best practice' and endeavoured to keep abreast with what students needed to prepare them for today's world. I wasn't fearful of trying new ideas, in fact, I considered myself stimulated by new ideas; that was what had kept teaching alive for me. Yet in science I held back. I felt that I should be able to answer all my students' questions, I knew I didn't have all the answers and it was this that made me reluctant to introduce science concepts in my classroom teaching. The problem was I also knew that it was in the moments when students were looking at science concepts that their eyes really shone and the questions came from every direction in the classroom. I knew I wanted to keep this curiosity alive and I wanted to continue to support my students to be successful in the things we did together, to engage them in innovative projects. But I knew that in science this was really hard for me to do.

STaL was the beginning of a change in my teaching. Three colleagues and I attended the program at Monash University with other primary and secondary teachers. We listened to science professionals grappling with the frustration of engaging us as teachers, encouraging us to use innovative strategies to build student

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confidence and develop a curiosity in students to enable them to research scientific issues. I understood that it was important for today's students to take responsibility for the sustainability of our environment and become scientifically literate but I wasn't confident about where to start. It was here, during these days that I was set free as a teacher. Suddenly it became clear to me that teachers did not have to have all the answers, but that it was far better to facilitate and guide students as they researched their own answers. The inquiry approach made all the difference.

A PIVOTAL MOMENT

As part of the STAL program I published an article on my science experience in the Year Three classroom. That article (a case I wrote about my teaching, see Howard, 2006) captured the essence of how I had hesitantly agreed to have silk worm eggs in the classroom. I had allowed students the time to follow their interest, watching these eggs hatch and develop.

This was a real learning time in my teaching career. I reflected on the action that had taken place and I realized the world had not ended because I had moved with the students' interest and deviated from the planned program. My Year Threes developed their writing skills, increased their sight vocabulary and their expressive language as they took their learning from the classroom to their homes. Parents and even grandparents became involved in these students' learning experience.

Reflecting on my own science teaching, reading the experiences of others (see, Loughran & Berry, 2006) and listening to the secondary school teachers reinforced for me a new personal understanding of my role as a teacher. I saw that I had to spend more time developing students' ability to discuss, and to be actively involved in exploring the science concepts that would influence their action in today's community and our environment.

I didn't have the answers but together with my students and the extended families, we were all learning about the world of silk worms and the construction of silk. We gathered information and the answers to our questions were there in the experiences we all shared together.

SPREADING THE WORD

In 2006 the Catholic Education Office offered Our Lady of Good Counsel (OLGC) the opportunity to become a Nucleus School and we published a collection of Science lesson reflections (Smith, 2007). The importance of reflecting on science teaching experiences was now a focus for me and I wanted to spread the word.

Many of my colleagues became interested in the STaL program and there was no shortage of others eager to take up the opportunity to learn about how to use the strategies that were common place in our Literacy programs in science based tasks.

My confidence to 'open the door' to science discoveries for my students developed. I had a new enthusiasm about science and I wanted others in my level, the teachers in the Grade 1 and 2 classes, to be excited about science projects too and waited for the first opportunity to do something about it - I didn't have to wait

long. Our level selected a unit on Force and Energy. Now instead of dreading these science lessons my mind was filled with ideas.

Our level decided to trial a project in which 4 classroom teachers would rotate through their 4 classrooms giving an immersion lesson. Suddenly we were all reflecting on the student outcomes and making changes to our lessons based on the needs of each group of students. Now instead of considering parts of the lesson that were less successful as 'mistakes', I saw them as an opportunity for me to reflect on the strategies I had chosen and to try different ways to engage the students.

When students brought their fathers into the class to build a moving vehicle this new approach to science was reinforced and I noticed that these 'mistakes' could now actually be used to create opportunities to genuinely extend their learning in new and meaningful ways. I could see and hear it in everything that was happening around me.

Remember when we tried that and it didn't work? Let's try it this way.

The axle is not turning, loosen the pins.

The classrooms were a buzz of learning. 120 students designing, testing, building and reflecting on their own creations and dads totally engaged in helping their children and those who were working alone. None of us really had the answers, but it was a fantastic morning of exploration and the students were learning - so were the dads.

Later in the year our Unit 'Sustainability in the Environment' challenged the students to research the needs of local birds and take action that was meaningful. After weeks of research and discovery, the students designed and created bird houses that went into backyards all over our local suburb. This was the kind of teaching and learning that all students needed to experience and fortunately the leadership team at our school appreciated the change in approach to doing science. Now most of the teachers in our team wanted to take part in the STaL Project and were ready to enrol when it was next offered.

It was obvious to me that as a team we were working together, we were valuing the idea of reflecting on our teaching and the students were totally engaged in their learning; this is what teaching should be all about.

GOING FURTHER

In 2007 the school Leadership Team agreed that the second Nucleus School project would be to introduce 'Scientific Literacy' into our school curriculum. When we accepted that challenge as an initiative for the whole school we knew it would be something special. I spoke to everyone about the idea and there were two types of responses. They had either no idea of what scientific literacy was or they had a view but there was little consensus; there was a variety of answers, all totally different. I decided to begin with scientific literacy as the language used to articulate, reflect on and describe science in our environment and future world. I decided it probably wasn't the best answer but it was a starting point. I kept telling myself now that we were all searching for answers.

Having the support of the Head of Teaching and Learning who had also completed the STaL course was crucial, and being able to employ a 'critical friend' for the

project made it possible for me to develop my confidence and take on the challenge with my students. I kept telling myself, "You don't have to have all the answers."

Under the guidance of the Head of Teaching and Learning the staff created a 'Through line' for our planning so that we could all focus our learning experiences around some common understandings. I found myself looking for links to the environment, to the students' changing lifestyles and the resources the community could provide. There were people in our parent body, in our local community and in large organizations that did have answers. I tried to find people outside the school that could and would be willing to engage with us to find answers to our questions.

Working with the Council's Parks and Gardens staff to plant local native trees and bushes in Linear Park, our nearby parkland, was a learning experience that demonstrated the need to create animal habitats to sustain the numbers of living things in our community. The students collected data, measured plants and wrote procedures for planting seedlings. Year one students started researching factual information and carefully followed the weather forecasts. Suddenly they were becoming aware of the impact our weather had on the environment and living things - including themselves. This, for me, was scientific literacy and I watched as students used the information supplied by other students to create their own answers to questions we had identified as a class.

Didn't you bring your bomber jacket, it is going to get cold this afternoon?

I don't think 18 degrees is that cold!

I personally knew little about local native vegetation but the council garden staff provided trees, valuable modeling and patiently provided a wealth of knowledge. We were all learning together and I was beginning to gain answers as well as the confidence to look outside my own knowledge to instigate students' interest.

The need to preserve water was one of the key understandings we wanted for our students in this unit so the natural extension was for the school to put in water tanks. We received a grant from the Science Department at the Catholic Education Office and the school joined forces with the Parish to share the costs of two large water tanks. The students were very aware of the need to value water and it was becoming an active part of their changed lifestyle at school. Each week we filled our plastic containers from the new tanks and watered the slowly growing trees that were battling through the drought conditions to survive.

The answers we were finding in each unit were becoming part of a plan for personal action - whether at school or beyond – and the students were becoming the experts. The level two students planted 400 small trees on a day that rained heavily and the laughter that echoed around the park reiterated what we all new 'Science can be and should be fun'. (Students would watch these plants grow into a native habitat over the coming years.)

THINKING DIFFERENTLY ABOUT EXPERTS

I often admitted to students that I didn't know the answer to their questions but suggested that together we could find them. Surprisingly, that was an acceptable

response and students seemed to see it as a positive and a challenge. It was interesting to watch individual students become the experts in the class, often different students, depending on the interest. Different experiences struck a chord with students. Suddenly they were bringing new learning to school, things they had discovered for themselves, articles they had read in the newspapers and experiences they had had out of school. Was this scientific literacy? They were questioning and discussing scientific issues that were happening in our community. Morning after morning I would arrive at school to hear:

Can I show the class this article about the earth becoming warmer …?

Can you believe this…?

Look at this photo of penguins covered in oil.

Hey! Mrs. Howard did you know ...?

I had to admit that sometimes I didn't know and I didn't have the answer to their query. Sometimes I doubted the information I heard but I always tried to answer in a way that sent the students off to share what was known and to find out more. I could see and feel my students looking for their own answers and I knew this was what learning should really be like.

THE WOW FACTOR

Learning for the future provided more personal challenges for me. I knew little about the 'new energies' or science for the next century yet I realized that this was the world in which my students would be living. Finding these ideas in everyday life and building excitement to stimulate real discussion was what I knew we needed. I knew that a little 'eye opening' experience would help so, with a visit from the Aura Solar Car, my eyes were suddenly opened to the enormous changes in energy that these students would see and experience in their lifetime. When the lorry pulled into our school yard and the solar car was unloaded my heart skipped a beat, secretly I liked the 'WOW' factor involved of science when it came along like this, and you could hear it in the student's voices:

Aliens have landed in the playground

It looks like a spaceship

Having Aura (the solar car) in the school was an exciting experience for students and staff and for an afternoon our imaginations went wild. I couldn't help but think that maybe that sense of excitement and active imagination were attributes of a successful scientist.

Students, wrote about the experience, read pages and pages of information, looked in the newspaper in an attempt to follow the path of the car and art classes featured drawings of Aura with some students designing their own cars through drawings. I tried to come to grips with the statement I had heard:

When you students are driving cars very few will be petrol driven.

A prep student asked:

What will happen to all the petrol stations?

This was scientific literacy. Even the youngest students were thinking about the impact of change in our society. Asking questions and looking for answers. (Students still come to tell me when they see the solar car on television making journeys across Australia, testing the endurance of solar power.)

Another question emerged for me through all of this – how do I make links between the wow events and everyday life? I still don't have the answer, in fact, I actually have more questions and so did the students.

Kathy Smith, OLGC's critical friend was someone we often turned to. When we were doing this unit, Kathy worked with each class group. She developed a lesson on solar power that was simple for the young and extended the knowledge of the older students. The value of having science expertise to support the staff was undeniably a great advantage and it prompted me to think about ways of capitalizing on the experience because I knew that students were learning more from doing than watching.

We engaged a visiting teacher with building equipment and tools. He set up his tools and resources in our art room and each student in our level built their own model solar powered car. Now students were transferring their new found wisdom and answers into action. Our classes discussed their cars with other students as they manoeuvred their cars around the playground with remote control hand pieces. This was so exciting.

Don't flatten my battery.

It's not sunny. Will the car go slower today?

I had gained some answers with the help of these experts. Students had developed answers - often beyond the simple concepts that perhaps I might have accepted in the past. I listened to 7 and 8 year old students explain how their solar car worked. Together we were able to draw the energy circuit, label it and for once I could really see that my students actually understood how the energy in the battery provided the force for movement. I realized that the language of science had become everyday language for these children. (Often it is the adults that find such language difficult to understand.) Scientific literacy was becoming a reality in each class.

There was a small group of year six boys who wanted to pursue their learning further and so through Monash University we were able to engage science teachers to work with a small group of students to build model solar powered boats. As a teacher I know that students retain far more when they discover the answer themselves, far more than when they are told the answers by someone else, now I could see it happening. Listening to the interaction between these students and the science professionals reinforced this for me. It made me think again about scientific literacy and what it really means in a primary classroom.

CHANGE ALL AROUND US

As other staff completed STaL, a changed science curriculum spread sending out waves like those from a small pebble thrown into a pond. As we continued to explore

and develop our focus of scientific literacy there were successes as well as less successful outcomes, but there were never failures. I watched each level as they unpacked science not only in environmental issues but in technology. The Year six students were gaining competency with cameras, video and film by making Slow-mations (Hoban, 2005, 2007) which they articulately explained and demonstrated to the school community. "This has to be a perfect example of the development of scientific literacy among students." I thought. I went into the Prep classrooms and I listened to the students discussing the life cycles of insects they had studied and then seen at the zoo. I looked at the detailed diagrams, heard their personal stories of encounters they had with these insects in their own gardens. They were engaged learners of science.

This can't be a spider because spiders have 6 legs.

Look at my snail. Where is the slime coming from?

For us at OLGC, scientific literacy belongs not only in the present but also in the future and in the past. When we were celebrating the 40th anniversary of the Apollo 11 first moon landing, students gathered around a display with older students explaining the photos to their younger 'buddies'. I could just remember this scientific exploration myself; so for the students all this had happened in 'the olden days'. But I knew that many students were also logging on to the suggested websites to see plans for future space exploration. A quiet little boy told me that his uncle was involved in the latest moon travel. He knew so much and when he was given the opportunity to share his knowledge with others, there was a class of wide-eyed peers.

To me this was scientific literacy in action and it was now a living language at OLGC. My answer to the question "What is scientific literacy?" has been developing each day through this journey I have been experiencing. With my students, together, we have been seeing science as a part of the future but also part of the past and present - and that is important. Suddenly students seemed to accept that we don't all have the answers, in fact answers can change with new learning and that is what makes science so exciting.

TIME TO PLAN AND REFLECT

Whenever I am asked what problem I face most in teaching my answer is always the same, "Time to plan and reflect." The Leadership Team at OLGC understood and valued the point that planning and reflecting are cornerstones for successful teaching. Our timetables were structured in such a way as to allow for planning sessions for teams with the curriculum coordinator and critical friend twice a term; week three to plan and week nine to reflect and make recommendations for change.

I would prepare for a planning meeting by reading the VEL (VCAA, 2009) Focus statements and I often felt lost for ideas. Over a couple of days I would think of things that could become a good starting point. I'd hear of people outside the school

community that could be a resource. I would then meet with my team. We were all so different in age, in experiences, and with classes as varied as us. The discussion that bounced around the table was amazing. Things that I hadn't even considered seemed so natural in researching the concept. Encouraging each other to follow the ideas we saw as relevant opened doors for us and our students. That approach is so important because it was through that flexibility our team became such a valuable resource for all of our students.

Our Literacy reading was often based on our science research. We incorporated the comprehension and decoding skills being focused on into charts and diagrams that we created and shared. There were limited resources for students in the younger years so we simplified teacher resources, used illustrations and built up banks of information that students could refer to for answers.

Looking at the weather, we were able to focus on writing procedures to create hail. One day, a wild storm had the students totally focused on the science of the unit and the school tuck shop freezer became the hail factory. The water cycle became less a mystery as students were able to reflect on their misconceptions and could all see the relevance and the joke of the water cycle diagram, sometimes depicted as a bubbling kettle standing in the middle of the field as an attempt to demonstrate evaporation.

CHANGE BEGINS WITH PLANNING

For so long we had finished a unit of work at the end of the term and then started out on a totally unrelated unit of work the following term. It was time to think differently about planning. At OLGC we now try to link the understandings achieved in one unit to the understandings for the next unit. Our units of work are purposefully designed to build on one other.

This year we began with 'Relationships' with students exploring and identifying how relationships impact their lives. Guided by our critical friend we linked this learning to the Second Term Unit of Sustainability. Here the 'through line' for each level was to develop an awareness of the commitment to sustainability of valued natural resources. We hoped students would begin to understand our responsibility to future generations to protect and enhance the world in which we live. The students found the links easy to make.

In term 3 students researched and discovered developments in 'Technology' and their impact on our changing world. A student in year three designed and built a water collector. He used an old umbrella, heeding the need to recycle, and articulately explained how water could be collected in the up-turned umbrella, flow down the tubing he had found and into the drinking bottle attached. He made these links without any input from me.

In Term 4 we chose to link what we had learned to a unit on 'Safety and Decision Making'. Students were now making their own decisions and making their decisions relevant and worthwhile - which was a priority in all classes. Our multi-domain planning then looked like the diagram in Figure 5.1.

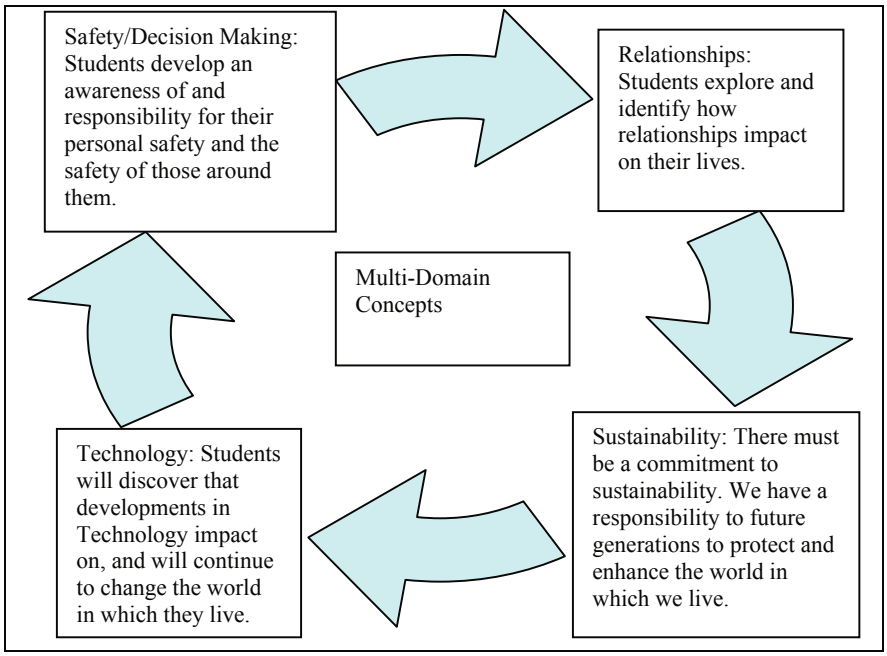

Figure 5.1. Multi-domain planning.

LOOKING BACK

I often wish I had recorded my learning over the years because the story would no doubt be one which reinforces the notion of life-long learning and the need for teachers to understand and foster this in themselves and their students. Of all the varied experiences I have had with students since completing the STaL program one stands alone as a valuable but simple lesson for me. Our class of Year 1's was studying plants and their needs in relation to healthy growth. I had planned a series of experiments with plants, evaluation and data collection tables, but I was trying to do too much. In fact having all the answers was making me move too fast.

I had been planting seedlings for years with students and I knew the facts I wanted students to learn so, in reality, I wasn't allowing them to find their own answers. Our critical friend agreed to teach alongside me in the class for a series of lessons. Step by step we seriously looked at each activity, each objective and the understandings anticipated for students after each lesson. (Students love experiments so I had no difficulty in engaging them but experiments need to provide answers too.) Kathy reminded me of something very important:

> Make the lessons simple, experiments should not try to demonstrate too much and the time frame for younger children should not be too long.

I will not forget this advice and the important strategies I learned.

No matter what the experiment is hoping to demonstrate, it really matters that we try to guide students to learn a little at a time. Students will still be totally engaged; they predict, they voice outcomes and they speak with confidence about shared findings when they are allowed to explore for themselves the things which capture their interest and curiosity. In that way, they seek answers and learn at least as much as we want them to; but often so much more as well.

We video-taped a small group of students talking about their learning and I was amazed at the extent to which they were able to use the understandings from these experiments, to make evaluations and predictions in other situations. They had recorded data, followed directions, made predictions and verified their thoughts with written answers that were well worded with scientific terminology and they shared these with the school community. They had been able to transfer the learning to community issues that would have real life meaning for them. I had the answers but because these students found the answers for themselves, the learning was more valuable for them.

MORE UNANSWERED QUESTIONS

There is no doubt we are on a continual learning path with our students but it is often helpful to see the success of our strategies, to confirm the achievements we have made along the way and to celebrate the answers we discover. Now as I look back on my journey of the last 5 years, I can see that I have come from being a teacher in charge of a limited science curriculum for students to a confident risk taker who allows students to lead the way within a cooperative learning environment in order to build up an evolving curriculum. I still don't have all the answers but this hasn't prevented me from asking more and more questions.

What was once a reluctance to begin is now gone. Challenges and excitement in science and the thought of empowering students to find answers and embark on new initiatives is at the heart of goals I now set for myself. Using the expertise and queries of students, the skills of colleagues and contributions available within the community now allows our level to plan, remain flexible and engage students in relevant experiences that promote research and develop answers to their many questions.

Taking the experiences of today, the technology that fills the lives of our students, and the changing world in which we live, means consistently changing the objectives in lessons. The inquiries that we facilitate with our students and the research techniques we instigate in our classrooms, influences how our students work toward (or not) solving their many unanswered questions - and those yet to be discovered.

Protecting and promoting our world for the safety and value of ourselves and for those who will come after us has to be a goal to be promoted amidst the action and unanswered questions for today's students. Embedding scientific literacy in our teaching is one way of doing just that.

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Mary Howard is a Grade 3 teacher at OLGC.

TRACY ADAMS

6. ACTION THAT MATTERS

PREVIOUSLY

Previously I thought the 'Action' of the Inquiry Process at OLGC (Our Lady of Good Counsel) had been something that occurred at the end of a unit of work. It was the evidence of knowledge and the culmination of a term's work. But as time went on and through many discussions with my colleagues, I realised something wasn't sitting right with me. There was always a nagging question at the back of my mind. Why did the action have to be at the end of a unit? This led me to more questions: Is action always hands on? Can it occur at different stages of learning? Could it look different at various stages throughout the school? A journey of discovery began.

NOW

After many planning sessions with my level and the leadership and guidance from the Head of Teaching and Learning and our critical friend and struggling with the niggling questions they would ask, ideas started to develop and gain some clarity. We were the ones who needed to come to an understanding of what we thought action was and where it would fit.

I have since discovered that Action can occur at many stages of the inquiry process, it can be teacher initiated or student driven but it is an essential, ongoing part of learning. It may be some initial trigger, a part of the immersion activities that the students participate in, something used to activate or engage student interest, or it may be something that occurs mid investigation to challenge the students' ideas and extend their thinking. It may happen at the end of an inquiry unit if that is the appropriate place. The focus for the placement of Action is where it will be most effective for learning; that is action that matters.

ACTION THAT MATTERS: FACING THE QUESTIONS

What is it? What does it look like? What does it sound like? What does it feel like? What has action got to do with scientific literacy? Why is it important to me? These have been challenging and important questions for me as I work to discover my own ideas about good Science Teaching and Learning and how and where these understandings fit with scientific literacy.

Learning that involves action that matters, asks the learner to explore their world through a number of lenses: Mathematical; Moral; Religious; Social; and, the often

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less considered scientific lens. Thinking about scientific literacy has been a way of conscientiously applying this science lens to tasks involving language, thinking and ways of investigating. This provides opportunities for students to develop a deep understanding and inquiring mind about what is happening in their world.

'Action that Matters' can be represented in a number of ways as evident in the following diagram (Figure 6.1).

Learning is NOT about gaining a head full of knowledge or facts it IS about what we do with ideas and thinking and how we apply what we know –that is learning.

Figure 6.1. Action that matters.

SO WHAT!

Today, Contemporary Learning for the 21st Century is challenging the learner to:
- understand their world;
- participate in their world; and,
- contribute to their world.

Learners require opportunities to action these words in meaningful ways, they need to investigate, understand, participate and contribute effectively to their world. This learning requires involvement and commitment from three major stakeholders in a school: the students; the teachers; and, the school's leaders. Parent support and commitment on the home front enhances these partnerships. Action that Matters can look, sound and feel very different depending on who you are and what you think and do in the process.

ACTION THAT MATTERS: DIFFERENT PERSPECTIVES

The Teacher – A Different Role

Four years ago I was invited to be part of a Science Teaching and Learning Professional Development course. It was a course that helped me to develop skills to improve student engagement and to discover new pedagogies in science. It was the first time in a long time where I was asked to stop, reflect and consider what it was that I did as part of my classroom organisation: What did I do?; What did my students do?; What did we say and ask?; Who led?; and, Who followed?

My experiences and discoveries in relation to these questions became pivotal to my practice, influencing the actions I took back in the school setting. This learning was also the impetus to continue this same discussion with my colleagues, to determine what we as a school believed about science teaching and learning. A further step was then taken with the guidance of our Head of Teaching and Learning and our 'critical friend' and this lead to OLGC being part of a Scientific Literacy Project. The project was "a planned intervention with a specific intention in mind. The intention was to lead to improved learning outcomes for students and to assist teachers to teach science more effectively" (Smith, 2010).

That statement opened a can of worms! We all had different ideas about what we thought scientific literacy was and what the learning would look like. The most valuable and interesting observation that I've made is that it has been a journey of discovery for us all. The idea of scientific literacy has been challenging for me, I am still defining what I think it is and how it might look and this is still a work in progress. I know that the notion of Science and science teaching has dramatically changed away from the view of the scientist in a white coat completing experiments. Now I consider the how and why of everyday events and experiences. That is what scientific literacy has done for me – and my students.

As I grapple with scientific literacy, thinking about 'Action that Matters' has been great for me as both the teacher and as a learner, it has made me reconsider my role as an educator. Three simple words, 'action that matters', but in reality, ever so powerful.

The shift for me has been in reconsidering my practice in relation to the questions:

– What can I do to allow the students more input into their learning?
– How do I guide possible directions for students' learning whilst still allowing them room to explore?
– How can I challenge them to develop deeper understanding?

What I have discovered is that questioning is all important - particularly the type of questions I initially ask in a topic. These questions are paramount; if effective they invite a myriad of responses from my students. In return I must be accepting of all their ideas and contributions without indicating that which is right or wrong. All things are possible at this important stage.

Giving the students time to use their language to add to the discussion is vital. Any definitions or understandings presented are accepted. When I changed my teaching behaviour such that I began to attend to these questions, I began to hear interesting comments from the students:

I like that definition...

I agree with you but what if we...

Could it be…

And from myself I began to hear:

Is there anything different that anyone would like to add...

That's what we think today. I wonder if we will think the same in a week?

THE STUDENTS: RESPONSIBLE, ACTIVE LEARNERS

I noticed my change in behaviour allowed me to actually listen to students' dialogue and I realised that their behaviour was also changing. They were clarifying and challenging each other; sometimes staying with their original ideas and in other cases changing because of what they had seen, heard or discovered. I began to think that this was action that mattered in their learning.

My responsibility had shifted from organising the answers and all the work to fit into a neat little box, to supporting the learners in their journeys of discovery and at times this could be just as challenging for me as it was for them. I noticed they were beginning to make connections to their world, they were asking questions as much as finding answers and trying to work out how this learning connected to them and what they could do with this information. This was action that was helpful to their learning and their thinking. This was action that mattered.

In my mind now scientific literacy means that a learner can ask questions and find answers to questions derived from curiosity about the science in their everyday experiences. In my mind this is action that matters. It also means that the learner can describe and explain their findings. I see this as action that matters. Students need to be able to argue their views based on evidence and apply conclusions from their arguments. This is action that matters. I think that scientifically literate learners identify scientific issues locally and globally and display their scientific literacy in different ways and I think this is action that matters!

LEADERSHIP: PROVIDING OPPORTUNITIES AND SUPPORT

Commitment from leadership provided specific time for planning and professional dialogue to occur. Each level of the school was able to meet with the Head of Teaching and Learning and our critical friend for an hour to open discussion and develop thoughts on learning for their students. Following this discussion, the levels would then meet on their own for half an hour to continue developing their original ideas and to gain clarity about where they were heading for the learning opportunities being planned. This was action that mattered for my own learning.

A conscientious effort was being made to include scientific literacy in our units of work, and this meant that developing meaningful learning opportunities really needed careful planning and discussion. These conversations were supported by the Head of Teaching and Learning and our critical friend. With their support we began to find opportunities to make connections between students' present learning and their learning from previous terms' work, and this became action that mattered for our planning and students' learning.

This approach was a major shift in my organisation and my way of working. It has proven to be a most effective and productive strategy which allows us to refer to previous learning when entering new ideas and concepts with students. Drawing on strategies, thinking tools and questions used from previous units has been action that matters in my teaching and students' learning and it has been most helpful; especially when working with the younger students.

ACTION THAT MATTERS: WHAT CAN IT LOOK LIKE?

Connecting Learning

I have been amazed with how connected my students have become with learning, the world in which they live and the questions they generate as a consequence of this connectedness. This has been action that matters. Working on a unit about Sustainability with Preps showed me just how interested students can be when they see that they can have an impact on the decisions that are made around them. From the work completed at school students discussed how they could be involved in sustaining our water supply and also the quality of the water so that it didn't harm aquatic creatures; Preps went home asking questions such as:

> What sorts of cleaning products do we use mum?
>
> Are they ones that can hurt our aquatic creatures?
>
> Can we go to the shops and see what other safe products there are?

This was action that mattered. The students became quite empowered that they could play a part in sustaining their environment. What blew me away was the feedback from parents about the conversations that their children were instigating at home

and the actions they were asking their families to consider in light of their learning. This was action that mattered.

Prep students were also involved in making a book about how to be safe at school. It came from a unit of work related to Safety. The students researched areas of the school where all students worked and played. This research was action that mattered. They gathered information over a period of time and recorded this information on a data chart - this collection and recording was action that mattered. Students then discussed the information they had collected and began to ask questions - this questioning was action that mattered. From there they worked out what behaviours needed to be exhibited and they designed a book that explained what needed to be done to stay safe around the school. This summary was action that mattered. This book was used the following year as part of the immersion into school for the new beginning Preps. Purpose, meaning and ownership of learning - this was action that mattered!

Connecting locally and globally with learning these days is important. Students from Years 1 and 2 with their teachers' support, made contact with the local council about the sustainability of the flora at the park across the road from the school. This communication was action that mattered. Students became involved in a program with a local ranger for the planting of small plants at the park and monitored and watered these plants. Rosters were drawn up, bottles were collected so they could be used for the watering and parents volunteered to support the students with walking them to the park for watering duty. The ownership of the action was empowering for students. The action also continued beyond the time of learning. This was action that mattered.

INSIGHTS

For Action that Matters to be a success and reality across our school, it has to be valued by the teachers, owned by the students, and supported by the leadership team. Knowing when to intervene and how, has been a learning curve for me.

Students have wonderful ideas that they want to explore and I need to allow them the freedom to explore but I also need to guide, question and troubleshoot along the way. Conditions for transference and application of knowledge need to have intentional and strategic planning involved.

If contemporary learning for the 21st Century is challenging the learner to:

- understand their world;
- participate in their world; and,
- contribute to their world,

Then I have a responsibility to nurture scientific literacy so that the learner can ask questions and find answers to questions derived from curiosity about everyday experiences. This is action that matters.

I also have to support them by giving them the language to explain their thoughts and findings; this communication is action that matters. The students need to include evidence to support their findings so they can then make choices; whatever stage of learning the students are at this is action that matters.

Professional Dialogue is vital and must occur at strategic stages of the learning process for both the students and the teacher. This is action that matters.

Action that matters is ongoing, it is changing, it is personal and yet it is collective. However it is defined, it is crucial to all stages of the learning process and it is the reason why learning is so important. I find action that matters all through our learning; it has changed my thinking, my practice and my students' learning.

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Tracy Adams is a Prep. Teacher at OLGC.

MICHELLE VERNA

7. 'Y' SCIENTIFIC LITERACY?

Five years ago when teaching Science to my primary school students, I placed a greater emphasis on teaching Science facts and Science terminology. I worked on a Science topic once a term, or more likely once a year. When the Science unit was over I would take down the classroom scientific display of the children's work at the end of the term, and that was it for Science for another twelve months!

Now my planning and teaching has changed considerably! It now involves looking at current issues in our society all year round. I look for ways that I can give students in my class the opportunity to engage in their own personally driven inquiries. This includes scientific issues or events in their everyday world, hence a real world context for developing their scientific literacy.

SCIENTIFIC LITERACY IN MY CLASSROOM LOOKS LIKE

In my classroom scientific literacy is evident when I can see students working together to form questions and determine answers using a variety of research skills. It involves students reading with understanding and being engaged in dialogue about a particular science issue. In this way, I see students developing the skills required to drive their inquiry into a science topic in meaningful ways.

Scientific literacy is underway when I see students asking each other questions, when they are reflecting on and responding to ideas and finding evidence to describe science knowledge, facts and information. They use their literacy skills to research and make informed decisions about scientific ideas. They then question and reflect when applying this information to current social issues and public debate is evident.

To achieve this with my students, I have found it is necessary to explicitly teach students literacy skills so that they can confidently read newspaper articles, watch educational DVDs, read non-fiction books, read magazines, research internet sites, and write questions with understanding.

I also find it important to work with students to develop the Maths skills they need to represent and to interpret data on science related issues in our society. Such issues could include exploring best sustainable practice and making informed personal decisions on health and lifestyle and seeing meaningful engagement and critical reflection.

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 67–74.

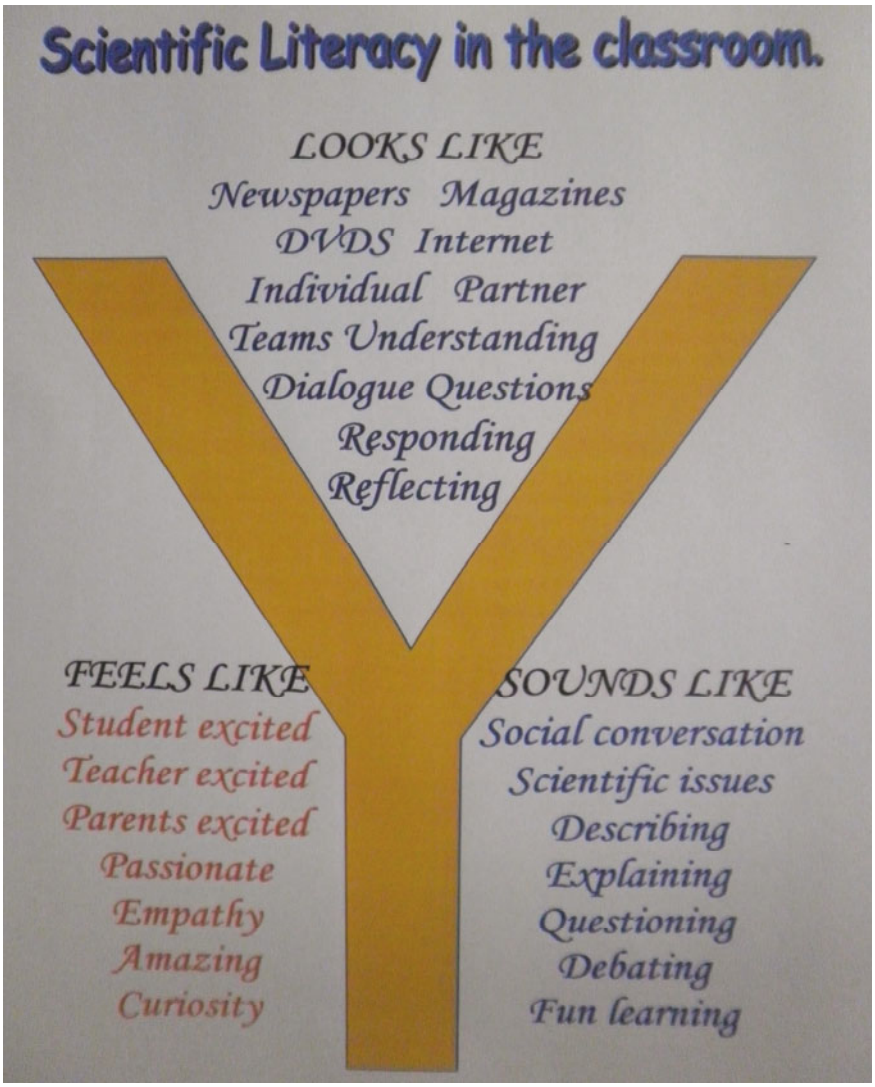
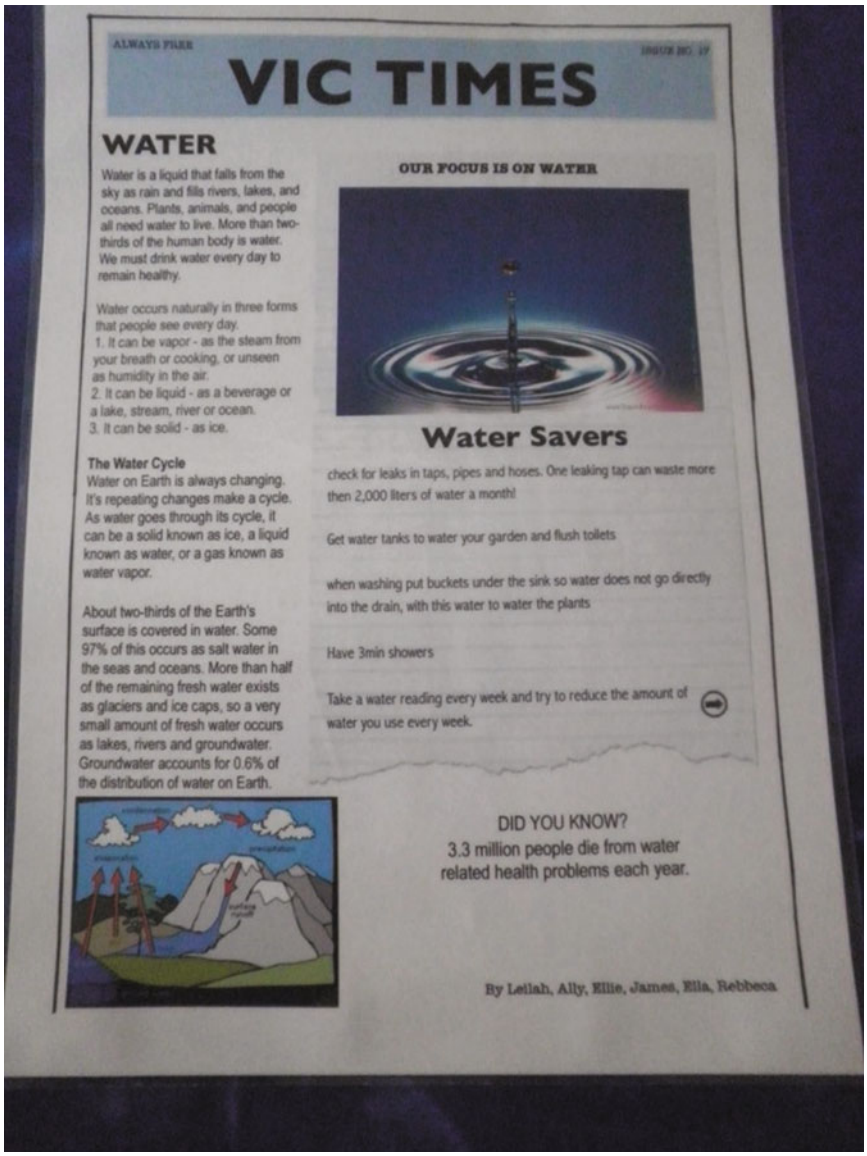


Figure 7.1. Scientific literacy in the classroom.


ALWAYS FIXER

VIC TIMES

WATER

Water is a liquid that falls from the sky as rain and fills rivers, lakes, and oceans. Plants, animals, and people all need water to live. More than two-thirds of the human body is water. We must drink water every day to remain healthy.

Water occurs naturally in three forms that people see every day.
1. It can be vapor - as the steam from your breath or cooking, or unseen as humidity in the air.
2. It can be liquid - as a beverage or a lake, stream, river or ocean.
3. It can be solid - as ice.

The Water Cycle
Water on Earth is always changing. It's repeating changes make a cycle. As water goes through its cycle, it can be a solid known as ice, a liquid known as water, or a gas known as water vapor.

About two-thirds of the Earth's surface is covered in water. Some 97% of this occurs as salt water in the seas and oceans. More than half of the remaining fresh water exists as glaciers and ice caps, so a very small amount of fresh water occurs as lakes, rivers and groundwater. Groundwater accounts for 0.6% of the distribution of water on Earth.

OUR FOCUS IS ON WATER

Water Savers

check for leaks in taps, pipes and hoses. One leaking tap can waste more then 2,000 liters of water a month!

Get water tanks to water your garden and flush toilets

when washing put buckets under the sink so water does not go directly into the drain, with this water to water the plants

Have 3min showers

Take a water reading every week and try to reduce the amount of water you use every week.

DID YOU KNOW?
3.3 million people die from water related health problems each year.

By Leilah, Ally, Ellie, James, Ella, Rebbeca

Figure 7.2. Student work on scientific literacy.

SCIENTIFIC LITERACY IN MY CLASSROOM FEELS LIKE

As a teacher it feels like I’m on an exciting learning journey with my students. This journey is derived from the curiosity and everyday experiences of students. I feel

their passion when they challenge and debate a scientific issue. I feel their motivation when they want to know what they can do to make a difference to their world when they explore a scientific issue. I feel empathy towards their discoveries in their learning. This in itself has challenged me at times when my own scientific knowledge or passion hasn't matched that of my students.

I remember a few years ago when I was in a Year 1 and 2 class and I had just finished reading a religious story. It was the Easter story about several women coming to the tomb where Jesus had been buried and a big rock had been rolled away. An amazing conversation began amongst the students as they began to share their opinions and question the situation and raise issues.

> This can't be true Miss Verna because a big rock has to break into smaller pieces to move away!
>
> Yeah, I'm sure my dad said once that lots of bad weather is what you need to make big rocks break away!
>
> Na, you're all wrong, big rocks just don't move, I know because I've been to Ayres rock and it never moved!

They challenged me with their statements and questions which required me to use my own scientific knowledge to explain how the rock had moved away. On that day, just saying it was a miracle wasn't enough! I then decided to set them on a challenge and explore how scientifically this may have happened. The facts, use of new terminology and sharing of newspaper articles related to scientific concepts to match their arguments was incredible. I even had parents getting into it as well!

SCIENTIFIC LITERACY IN MY CLASSROOM SOUNDS LIKE

I hear myself and my students talking differently; engaging in social conversation about scientific issues that capture our curiosity. I can hear students describe and explain as well as question their findings.

This year in my Year 5 class when exploring a topic about relationships, my students had to discuss the relationship between purchasing a product and how that purchase might impact their world. For example, I had a group of girls who chose to look at purchasing make-up. They headed off on a bit of a tangent and looked at the ingredients of lipstick. As a consequence, they discovered that different minerals and oils are used and a conversation emerged about how certain chemicals could be mixed together; scientific literacy in action.

They started to explore how liquids used in make-up could then be turned into a solid. They began to confidently share their knowledge and understanding of scientific processes to make informed decisions about a debatable scientific issue in their world. Another group decided wearing perfume wasn't such a good idea after all. The debate as to whether or not people should be spraying chemicals into the air and its impact on the environment arose.

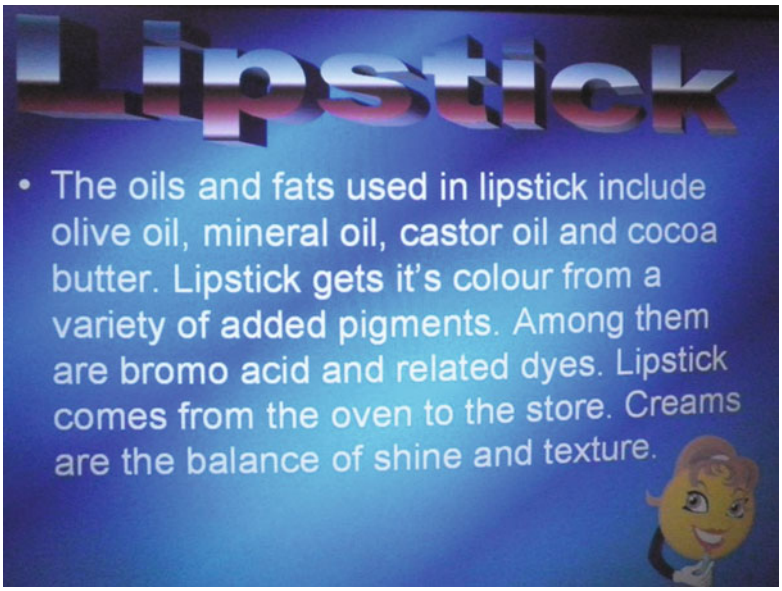


Figure 7.3. Student work on lipstick.

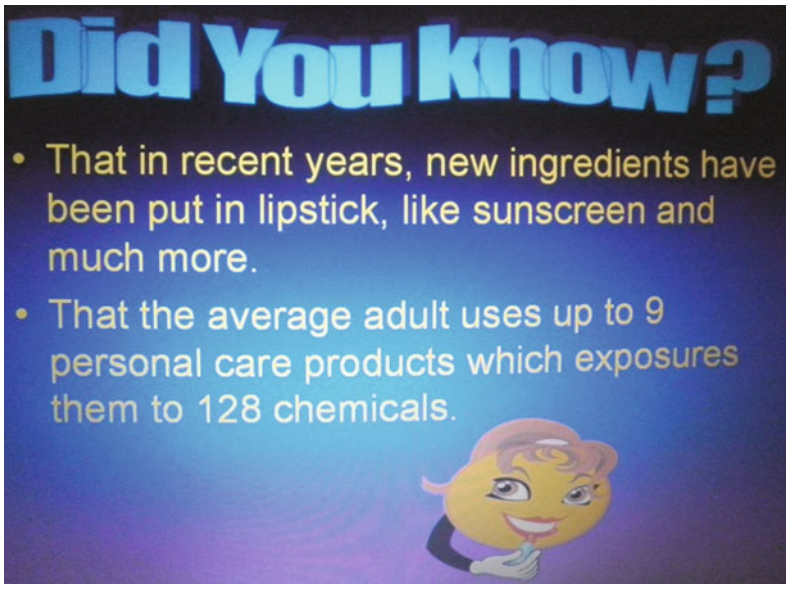


Figure 7.4. Student work on lipstick.

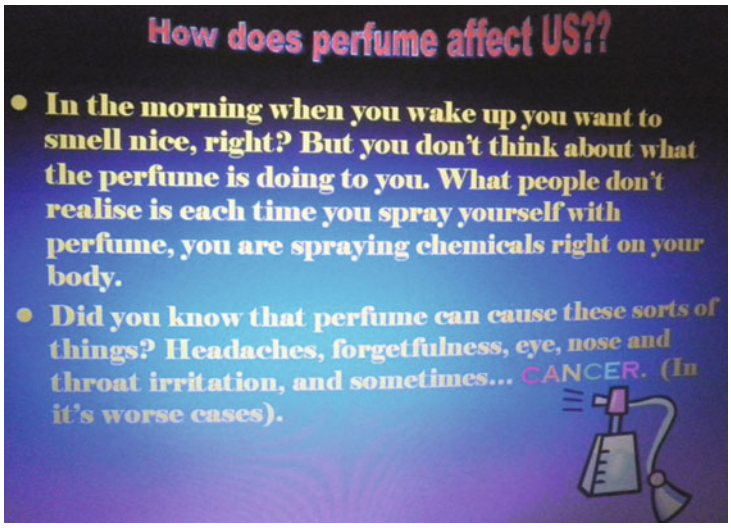


Figure 7.5. Student work on perfume.

KEY ELEMENTS OF SCIENTIFIC LITERACY THAT CONTRIBUTES TO BEST TEACHING PRACTICE

As educators, I feel as though our priority should be to ensure that we encourage our students to:

- be interested in, and have an understanding of the world around them;
- engage in discussions about science;
- be critical and question issues about science;
- identify questions and investigate science whereby they can gather evidence to make conclusions; and,
- make informed decisions about their environment and their own health and well-being.

I now find myself asking, how can I as a teacher most effectively engage my students with common science ideas and concepts so that teaching and learning practices contribute to the development of scientific literacy?

The answer usually involves a lot of hands on experiences and the use of media tools to engage students' interests straight away. I continue to keep in mind the notion that laying down strong foundations in science education is very important in the Primary years. I think as teachers that we need to ensure that we explicitly teach students what makes good questions, how to express an opinion through Exposition writing and the oral skills to be able to confidently debate a topic. We need to ensure our students in the Primary Years are literate enough to become informed about science knowledge and ideas.

It is important that we provide opportunities for students to undertake extended science inquiries motivated by their interest in real world scientific issues. In so doing,

they broaden their experiences of scientific inquiry which provides them with a natural opportunity for integrated learning. Such a process allows students to take ownership, share and control their learning with others.

TANTALISE PARENTS AND OTHER TEACHERS TO COME ON BOARD

On my journey I have begun to excite and encourage parents and other teachers to explore scientific literacy further. They too are coming to understand that our world is increasingly driven by science related issues. Hence, achieving scientific literacy as an educational outcome is becoming increasingly important. Students only need to look around our environment to see the growing demands being placed on individuals and society to understand the need to engage in science research, to develop a view or reflect on a science application.

More and more parents, as well as the school, are beginning to understand the influence their views or practices have on our children. It is increasingly important to educate parents/teachers early in the year that science teaching today is not all about recalling facts, but about opening up to and acknowledging the need to learn and demonstrate the confidence to find out more about a particular scientific issue. For instance, we've had several parent nights calling upon members of the Science department of Monash University and the Catholic Education Office to speak to parents about where science education is heading and what scientific literacy means. We've also held Drug education and Human Development nights where parents, teachers and students become more informed about science in our society. Multi-domain afternoon exhibitions within the school have been held where parents have been invited to come along and see what their students have been doing in class. Science has also become a regular focus in school newsletters.

At OLGC we have worked closely for many years in team planning sessions often facilitated by the Head of Teaching and Learning in combination with our 'critical friend'. Together we have worked towards planning and identifying scientific literacy of our topics. We've tried to ensure that student-centred inquiry is driven by real world issues. This approach requires the blending of knowledge from different curriculum areas as students think and act in a scientific way. Scientific literacy not only involves knowing, but also includes a way of thinking and acting and our approach has offered Professional Development that has significantly influenced our planning as well as our teaching and learning practices.

THE 'BIG IDEAS' THAT SHAPE MY TEACHING FOR SCIENTIFIC LITERACY

In my experiences in the classroom, there has been great value in planning with a team who value scientific literacy. The team sees scientific literacy as a learning outcome and have in mind the 'Big ideas' for implementing scientific literacy which include:

- being aware that science is all around us;
- identifying early meaningful science issues;
- encouraging student engagement;

– laying strong foundations for student inquiries; and,
– parent/staff education and involvement in student centred learning.

Having this shared understanding makes planning and teaching easier because teachers begin to agree on the skills and the learning that they think needs to take place.

Finally, my current practice highlights for me that to develop children's scientific literacy we should be concentrating on the quality of understanding rather than the quantity of information presented. This can be evident in their inquiry into a scientific issue and has significantly impacted my teaching as I have come to see that when students take control of their learning, their understanding is markedly enhanced. They can do this by asking questions and forming strong opinions related to specific science concepts.

My scientific literacy learning journey has seen me critically reflect on my own prior experiences of science teaching and learning and in so doing, it has led to a positive shift in my thinking about the purpose and practice of science education.

Michelle Verna is a Grade 5 teacher at OLGC.

MARGARET HOSE

8. LAYERING

A Personal Journey

We have learnt from the Europeans how effective layering clothing is in a cool climate and in education we've recognized the value of including students' prior knowledge in developing and broadening their understanding when teaching something new. We've even become quite adept at encouraging our students to reflect on their learning and set future learning goals. However, it doesn't seem to me that there has been much consideration given to the sequence of steps along the way that lead to learning – steps that I call 'layering'. In this chapter, I recount my learning that I understand as the 'layers' I have acquired during my passage of understanding about scientific literacy.

LAYER 1: DEVELOPING AN INQUIRING MIND

As children growing up on a farm, my siblings and I were quite resourceful and self-sufficient when it came to entertainment; even in providing for our food needs. I remember each autumn, we were duly sent out to roam the paddocks in search of mushrooms, which were often quite difficult to see among the tufts of thick, course grass. The trick, we discovered on arrival at a suitable site, was to stand tall and perfectly still and rake your sights over the ground in a very methodical grid pattern until finally you glimpsed little smooth, brown mounds standing out among the taller grass. Then the race was on to see which of us got there first!

That skill was repeated until our baskets were full, or the whole paddock had been covered. After some practice, it became more apparent which signs were useful in giving us more insight into the best spots. Was the grass greener and more lush? If there was one mushroom, would there be others hidden in a ring-like cluster nearby? Even more important, had the sheep and cows been in the paddock recently kicking everything over? Later it was about whether the grass had recently been given a dose of superphosphate because as the farmer in us knew, super is the death of mushrooms!

As I look back on it now, without realising, I was developing observation, analysis and logistical skills, as well as applying informed knowledge from my father, in a completely natural, free and fun environment. Needless to say, I have used these skills all my life and I believe that these are the stepping stones to developing an inquiring mind. They are also some of the skills needed in developing scientific literacy.

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 75–80.

LAYER 2: SETTING THE SEED TO SCIENTIFIC LITERACY

Although I wasn't aware of it at the time, a teacher survey given at a previous school several years ago was the catalyst for an unsettling observation. A question in the survey read: "Do you ever give 'stand-alone' science lessons?"

As I had recently returned to teaching after quite a long break, I had no idea whether I should be answering 'yay' or 'nay'! No-one else seemed to really have the answer either, and what's more, no answer was forthcoming from those at the top. The consequence was that I stopped giving the ad hoc, but contextually appropriate lessons that I had always done, and restricted my science teaching solely to planned science units. But the question remained in my mind, "How were we meant to be teaching science?"

LAYER 3: VISIT FROM AN EXPERT ON SCIENTIFIC LITERACY

They say knowledge is power, and knowledge and the O.K. from a visiting expert was all that was needed to set my mind thinking again about science and the way it was taught. The expert was Simon Lindsay from the Catholic Education Office. I hadn't heard of scientific literacy before, but I certainly had 'used the moment' to allow for an impromptu science lesson (or any other kind of lesson) and I always observed that students were very engaged when this happened.

I'm sure that I would have used science stories, articles and pictures before too, but YouTube was alien to me then, but nevertheless, very exciting. Simon also talked about the many skills of a scientist that can be carried over to other areas of learning to such an extent that they become part of life. I had my first inkling of what it meant to be scientifically literate.

LAYER 4: FIRST ATTEMPTS AT CLASSROOM IMPLEMENTATION

I began to use some of these ideas in my teaching. I scoured the newspapers for any articles that faintly resembled science and usually included them as part of the literacy program, or made a newsboard, such as I had so often done in the old days. I don't believe that I had got to anything deeper, such as analyzing, looking for evidence, categorizing, testing theories or creating hypotheses. I have to say that although interesting, I questioned whether being scientifically literate was the same as being critically literate, or simply a part of any good teaching and learning. There was obviously more to it than this.

LAYER 5: LOOKING FOR SCIENCE

So far, our planning team had stuck to focusing on the key understandings that we wanted our students to get out of a unit of study. In some cases this meant no science whatsoever. In class, we had looked at science stories from current happenings, but they were usually unrelated to each other, and often not linked in any way to our multi-domain topic. However, we were confident that we were including scientific literacy in many aspects of our learning and felt it was a big improvement on what had happened in the past.

Danger was lurking around the corner though, for come end of semester reporting time, we realised to our horror, that we had not included any specific science assessment at all. This calamity was the trigger for us to urgently begin looking for explicit science in every unit covered.

Obviously, the issue of not being able to include elements of strong science in non-science topics indicated that there was a need to develop skills associated with being a scientist (i.e., scientific literacy). However, it also seemed imperative that we should include some related science in a more controlled and organised way so that it formed an integral part of the unit and also hopefully linked one topic to another. This aspect of linking would not only add to the 'layering' of knowledge, it also meant that scientific content did not have to be equally strong in every unit (as long as it was present within the reporting time frame). However, a problem still remained, "Where to find meaningful science?"

LAYER 6: GOOD LEARNING, GOOD SCIENCE

During 2009, I attended the STaL program and through that I became more informed about better ways of teaching science which included:

- asking probing questions which lead students to think of alternative explanations or points of view;
- allowing students to have 'wait time' to really get them to think deeply and explore their own thoughts by 'bouncing back' with other students' ideas;
- modelling neutrality as a teacher by holding back on judgements and allowing students to work towards their own understandings; and,
- valuing all contributions so as to encourage input from more students.

At the first seminar, all participants were issued with a gem of a book called *Whose learning is it?* (Osler & Flack). From reading this book I became interested in what constitutes good learning behaviours: such things as making links; asking good questions; making choices; and, analyzing and reflecting on one's own learning. *Whose learning is it?* offered me a new way of thinking about good learning and the ideas developed in those pages certainly caught my attention.

Through my own reflection on my learning so far, I realized I needed to implement some of the ideas about good learning, so I programmed a whole class inquiry into what students thought constituted good learning. This was a good beginning, but a few days later, it was my chance to set the direction further.

In class, we had been reading a story in literacy time, and in the same book there was a procedure on constructing a diorama about seahorses. During Share Time several students asked if they could make their own diorama. I agreed, but thought no more of it. However, a few days later, one student hustled into class with a box covered in a cloth and asked if she could share. Once again, I agreed, but I thought I would try to get more out of it than just showing her handiwork.

I asked the class to think of 'how' and 'why' questions that they could ask. What they discovered for themselves was that making the diorama entailed using construction, colour experimentation and visual effects skills. What more could there be? Yes there's more! Find out about seahorses - biological science. What sort of habitat

do they need? - environmental science. Point taken! Another step in integrating scientific literacy into our curriculum!

LAYER 7: CONSTRUCTING A BETTER SEQUENCE OF LEARNING

In a previous Level 3 Communication unit called *Selling Our School* our level had success in using a 4 Step Inquiry Method devised by a marketing expert. This model worked well because it was simple and the students always knew where they were at in their inquiry. It made sense to try a more generalised model which could be used for any area of the curriculum, and at any level.

The *Problem Solving and Task Manager* - ABCDEQ method (see Figure 8.1) was used as a trial for the *Sustainable Model House Inquiry* instead of a formal design brief in the 'Design, Construction and Technology' unit at Level 2. The purpose was to give students a process to follow which they could easily remember, as well as being able to use it continually throughout the unit to reflect on each step of the process. This was also useful in getting students to think through problematic behaviour issues.

Table 8.1. ABCDEQ method

PROBLEM OR TASK MANAGER		
A	ASK	**THINK** What do I know already?
B	BRAINSTORM	**TALK** Share your thoughts with others
C	COLLECT IDEAS	**WRITE** Choose the best **KEY IDEAS** or **PLANS**
D	DECIDE	**DECIDE** Agree on 2 designs or plans of action
E	EXPLAIN	**PRESENT** Tell/ show what you have designed or made
Q	QUESTION	**REFLECT** How did it go?
FOLLOW the steps. *REPEAT as many times as you need		

LAYER 8: INCLUDING SCIENCE IN A LEARNING SEQUENCE

It is possible to find relevant science in any topic that is covered. For example, in the early settlement of Australia how did Captain Cook solve the problem of scurvy when sailing long distances? Looking for science in the unit *Sustainable Model Houses* was not so difficult. The science ideas we used were, hot air rises in two-storey houses, and north facing houses in Melbourne are more energy efficient - which was a nice fit with our previous topic of sustainability. This unit was also great for mathematics as it included a lot of measurement – length, perimeter and area, some fractions and tessellations (as in tile designs for bathrooms).

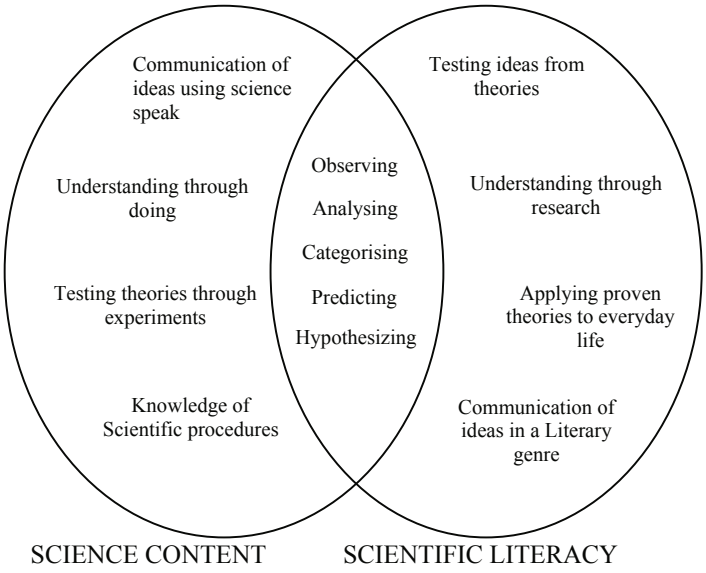


Figure 8.1. Venn diagram.

Another way to include the literacy part of science is to experiment with mini-inquiries. While endeavouring to include science into every topic throughout the year, my class began a record of science articles and items from those brought in for discussion by the students. This made them more aware of science in the world around them. We made lists of scientific terms we encountered, and it also led to some small mini-inquiries in the literacy block which could be associated with an area of relevant science, using various genres and designated skills such as research and hypothesising. For example, the Venn diagram (Figure 8.1) offers one possible view of the difference between scientific literacy and science per se.

SUMMARY

The roots of scientific literacy have taken hold and I am finally comfortable with my understanding of what it means. Perhaps for me, an acceptable definition of

scientific literacy is the ability to use and understand scientific language and concepts in an appropriate context. But whatever it is, it now seems as though scientific literacy is no longer a separate entity - it has merged into my being and seems just as natural as any other literacy.

In working through the layers of my personal journey, I have discovered that scientific literacy seems to require:

- life experiences that expose children from an early age to a variety of challenging ideas, skills and responsibilities;
- an input of knowledge and modelling acquired from experts or other sources;
- trained observation skills – people see different things, but we need to see the significant things which sometimes needs guidance;
- prediction – making informed decisions based on some facts, which may not always lead to the correct conclusions;
- the employment of logical thinking processes and tools to analyse data;
- decision making based on logical or proven data;
- the process is more important than the result; and,
- an understanding of what a hypothesis is – it is not necessarily a truth.

It has taken me a lifetime of learning, a need to be patient, to think outside the square and work with guidelines to become multi literate. The problem for 21st century students is that as their teacher, I want it and need that to happen NOW!

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Margaret Hose is a Grade 2 teacher at OLGC.

ANTHONY WALSH

9. IT'S MULTI DOMAIN

But Where's the Scientific Literacy?

> *Isn't it something to do with, um, the science around you or something? (Molly)*

Make no mistake about it. I am not an expert on scientific literacy. What I am is a classroom teacher who has immersed his class in the idea of it. Finding a starting point, or even an angle for that matter, is really difficult when you feel as though you don't know any more than the next person. This is the greatest difficulty that I had when sitting down to write this chapter. Learning about scientific literacy is not a journey that I am taking on my own; it is one that I am doing with colleagues, and daily with the children in my class (Year 6W).

To begin gathering perspectives and information on the subject, I decided to sit down in small discussion groups with my students to give the chapter some authenticity. All discussions were audio-recorded and it is these views that are quoted throughout the chapter. As already stated I am not an expert on scientific literacy, but I do have experience in its application. It is my (and my class') experiences that I will share through this chapter.

AN OLD FASHIONED VIEW OF SCIENCE TEACHING

For many years I had taught my class in a fashion that was thought to be reasonably contemporary – term long units that covered eight major topics over a two year cycle. This enabled me to teach, potentially, two or three in-depth science units along with the obligatory science week activities. I felt as though I was doing a good job and was covering the curriculum as required in that time. It's funny how you always feel that you are doing the most current thing, but with the benefit of hindsight you are lucky to see things as they really are.

As my level of experience has developed I have been fortunate to partake in many opportunities that have furthered my thinking on what it means to be an effective teacher of science, and more specifically, teacher of scientific literacy, in the primary classroom. It began with some wonderful insights at the Science Teaching and Learning (STaL) project facilitated by Monash University. That experience was taken to another level when our school participated in the Scientific Literacy Project. For me, however, all I had learnt was enhanced when I was lucky enough to travel to Christchurch, New Zealand, to observe some of the strategies and methods being

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 81–92.

used at the Discovery 1 School. It is definitely a combination of these experiences that has had great influence on the application of scientific literacy in my classroom.

A NEW APPROACH TO UNIT TOPICS

> *The topics that we do all have some element of science in them, for example the science of technology, the science of sustainability, the science of the human body, the science of maths, the science of… anything. (Luke)*

At our school we have developed less of a need to plan units that are specifically domain, or curriculum area, based. There is no longer a scope and sequence that tells us that we are covering a health unit, a science unit, a history unit and so on. While we do still have themes that run through the school they are based more broadly on topics such as safety, communication and sustainability. It is through the inquiry of these topics that we are able to incorporate teaching and learning of all relevant subject areas.

Although in the teaching of some things, for instance mathematics or physical education, there are times that a subject can only be taught in the context of the specific outcome, it is our aim to continue the theme throughout as much of our teaching as we can. An example of this is that if we were looking at the topic of sustainability, we would be reading newspaper articles and journals, information texts, etc., to teach comprehension and writing genres all based on that theme. In Religion there would be discussion and activities based around the idea of sustainability and making our world a place for our families to live in the future. In mathematics we would be looking at surveying the school to do some auditing, measuring our consumption and so on. The same principle applies for science through the practice of scientific literacy. Rather than teaching science as a standalone subject it too is integrated at every suitable opportunity.

Scientific literacy has been one of the great drivers for this way of thinking for me. It has been through my understanding of the need to identify the science in everyday experiences that I have developed a mentality that has me looking for it as second nature.

> *It can be historical and it can be present, as well as a lot of futuristic stuff. Exploring the past and seeing what it will be like in the future. It gives us a better knowledge of what's happening around us. (Saskia, Emma & Hannah)*

Having a whole school approach where scientific literacy is at the forefront of our planning has been a very great change to the teaching of science. There have been other elements that have also contributed to this improvement. The management of the school has catered for specific level planning sessions to be conducted twice per term, where the focus is not on planning activities and collecting resources, but on reflection on the work we are doing in multi domain and forward thinking towards where the science will be found in upcoming units.

These sessions are facilitated by the Head of Teaching and Learning from the school, and our 'critical friend' in the form of a consultant with a passion for science teaching. It is fantastic to have a couple of tuned in people to guide our thinking, to make sure that our group is working sequentially with the rest of the school to give us good, sound advice that comes from an expert background in the subject.

The other initiative that has really led our push towards scientific literacy has developed out of the *Leadership for Contemporary Learning* project that I, along with several others of our staff have been attending. It has given us a plan to ensure that our teaching leads to action that matters. This blends very nicely with the scientific literacy project, meaning that we really are concentrating on the content of our learning coming from what is happening in the world around us, and subsequently trying to use our learning to make some kind of impact (usually in our school or local community).

ACTION THAT MATTERS

Something that became evident after a few units was that the action that we aimed for could look different in a number of ways. For some levels and for some units,

the action could be very evident and immediate. However, there are times when the action that the students perform may not be evident for years to come. An example of this was when we did a lot of work investigating the impact of our production and consumption on the environment, our findings led to a good education on decision making. Whilst there may be evidence of the students understanding, it is our hope that the choices that they make in the future will actually be the time when they are performing the action that matters.

The element of action is a vital component of scientific literacy. We talk a lot about the impact of science in the world around us, but it is important that the knowledge we gain from the study of scientific literacy is put to effective use for the future benefit of our world.

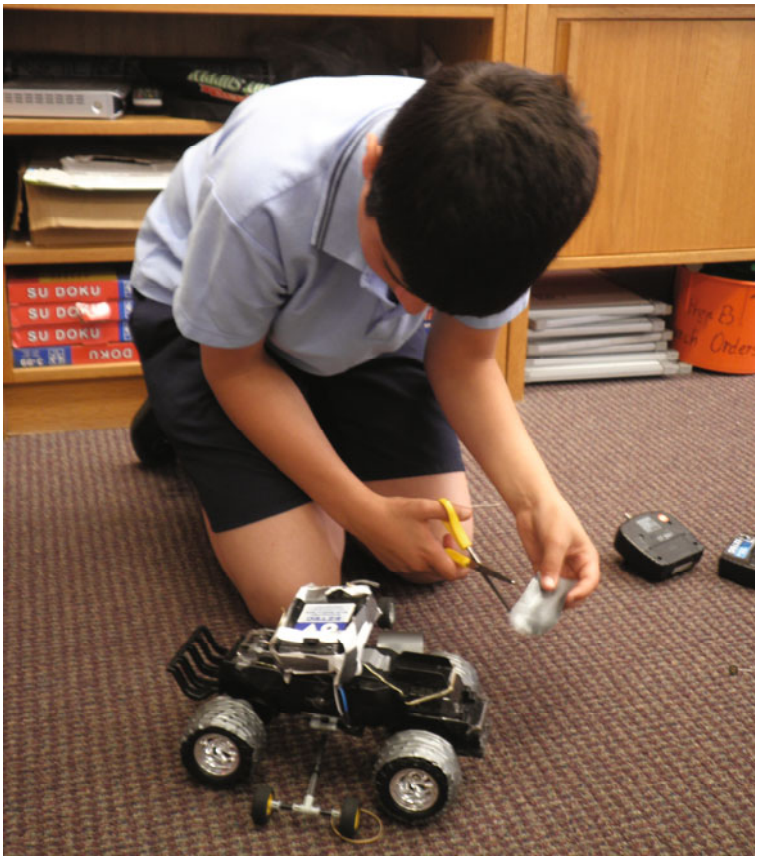
A TEAM OF CHAMPIONS OR A CHAMPION TEAM?

> *It's good because the teachers don't just put you into a group. They put us into a group that is going to work well. It's not just working with your friends. You get to work with people who have the same interests as you. You may not like it, but you know it's the best thing for you. (Nick, Luke & Tiarnie)*

Having taught in the senior levels for the past five or so years, I have learnt that children respond really well to project work that caters for a multitude of curriculum areas, learning styles and presentation types. That is, if the project is developed to be authentic and flexible enough to cover a range of individual interests of course.

One of the great advantages of providing opportunities for the students to work in this way is the dynamic nature of working in teams. In my career as a teacher to date, I have used a variety of strategies to group children for project work. I have tried allowing them to work with friends to keep them happy. I have tried placing them in groups away from friends to avoid distraction. I have mixed groups into boy/girl combinations and I have even used numbering systems. It has only been recently, however, that I used a grouping system that has met with a positive outcome on all sides. The students are happy, there is less stress on the teacher in creating groups, the work is getting done and more importantly there is evidence of higher quality work.

The strategy that we are using is for the students to develop the list of categories available to research (group brainstorm), and for them to then select the topics that best appeal to their interests in order of preference. This allows students to be grouped into teams where they are studying topics that they will be motivated to spend time on and are amongst like-minded peers.



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

STUDENT DIRECTED LEARNING – PERSONALISING THE INQUIRY

> *In a lot of things we do, you don't have to put it in, it's already there. We've got to find it. It's good. It's not just what you guys (the teachers) want us to do. It becomes more a personal choice. We have more of a say in what we want to do (investigate). (Molly)*

As stated earlier, a multi domain approach is the direction that we have worked in for the past few years. Recently I have worked with my team and the students in our level to think of lines of inquiry that will accommodate all facets of teaching and learning. This has not always been an easy task, but it is one that when worked on can be quite effective.

The process that we go through is to initially immerse the students in the general theme of the term's topic. This includes reading and internet research time, comprehension tasks, viewing of videos and clips, and a lot of work with graphic organisers and thinking tools to get the group thinking about the direction we might take. Up to this point the learning activities are usually set and run by the class teacher, though we tend to join our three level 4 classes together and mix the students in a variety of ways for this. But, when setting the work for the remainder of the unit, we come together as a group to brainstorm ideas for the aim of our project. The aim is to be general enough so that it can be applied and investigated for a multitude of chosen topics.

Some examples of aims we have developed include:

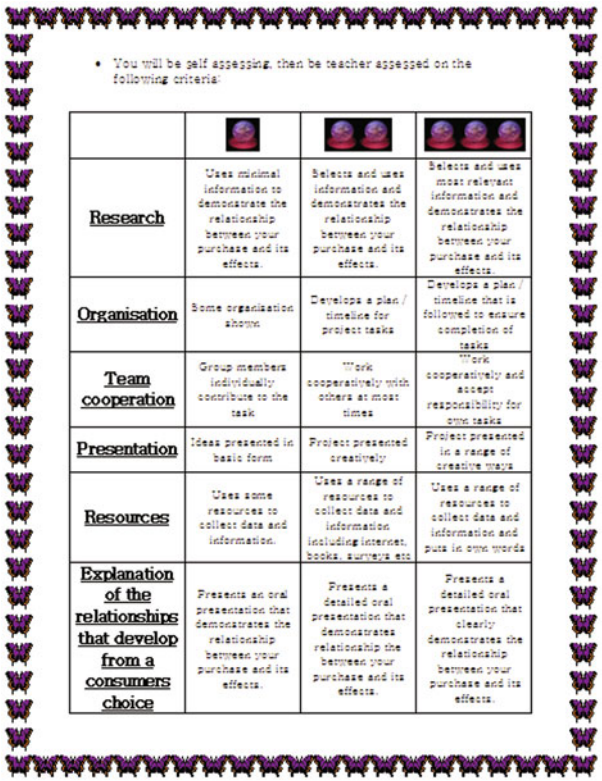
> *To investigate sustainable practice and implement ideas that can help our school and local community, become a more environmentally friendly place and to investigate the relationships that develop out of a consumers' choice and the personal, social, environmental and economic impact that choice has.*

Using one of the above aims as an example, it allowed one group to investigate the effects of antiperspirant deodorants whilst another group wanted to work on tyres as they had an interest in cars. Yet another group was able to study the impact of book production. Each of these groups, though diverse in their topic choice was able to identify the relationship that buying a product had on their world and the community around them.

Having looked at the general aim of our learning, it is then important for us to look more specifically at the focus questions that will guide the direction of our learning. The children are split into small mixed groups again at this point. Their role is to think of things that they want to know about the general topic and to write some questions that will help them fulfil their inquiry.

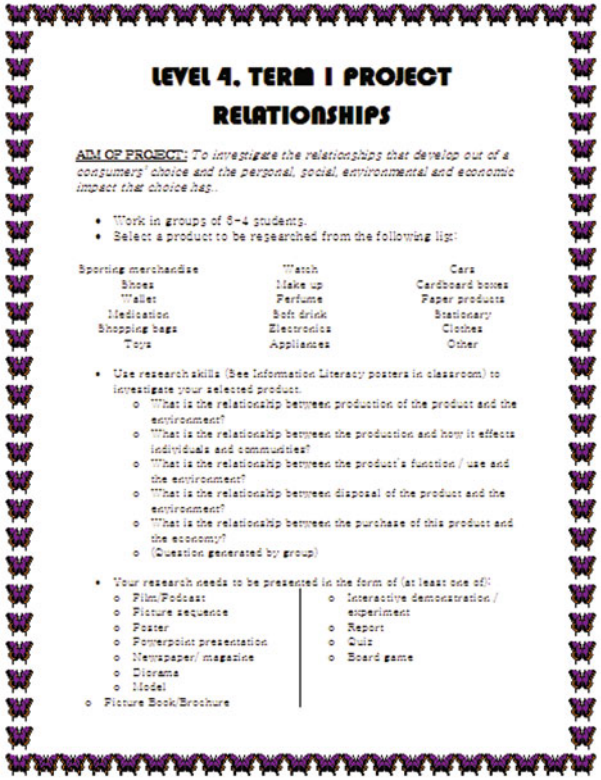
Each group develops a couple of questions and then these are shared with the rest of the larger group. At this point, anybody that has something to share is welcomed and there is no putting down of people's questions. Every question that someone has is a valid question in its own right. The questions are then bundled to see if there are any 'like' matches, and they may then be reworded by the group to find the most succinct, well defined wording for that question. Eventually we narrow it down so that we have 4–6 of the best focus questions to pursue. This can be a time consuming exercise at times, but the value of the children owning their own line of inquiry is priceless.

Now that we know what the specific focus of our learning is going to be, we then list those more specific ideas that we want to find out more about. As teachers working together, we will have met before this and thought about our plan for the direction, but we do not set the agenda, rather we allow the students to make these kinds of decisions. That is not to say that we are not involved in the process and that we don't have any influence on the discussion, but in the end the power and ownership of the learning is handed over to the students.



- You will be self assessing, then be teacher assessed on the following criteria:

Research	Uses minimal information to demonstrate the relationship between your purchase and its effects.	Selects and uses information and demonstrates the relationship between your purchase and its effects.	Selects and uses most relevant information and demonstrates the relationship between your purchase and its effects.
Organisation	Some organisation shown	Develops a plan / timeline for project tasks	Develops a plan / timeline that is followed to ensure completion of tasks
Team cooperation	Group members individually contribute to the task	Work cooperatively with others at most times	Work cooperatively and accept responsibility for own tasks
Presentation	Ideas presented in basic form	Project presented creatively	Project presented in a range of creative ways
Resources	Uses some resources to collect data and information.	Uses a range of resources to collect data and information including internet, books, surveys etc	Uses a range of resources to collect data and information and puts in own words
Explanation of the relationships that develop from a consumers choice	Presents an oral presentation that demonstrates the relationship between your purchase and its effects.	Presents a detailed oral presentation that demonstrates relationship the between your purchase and its effects.	Presents a detailed oral presentation that clearly demonstrates the relationship between your purchase and its effects.



LEVEL 4. TERM 1 PROJECT

RELATIONSHIPS

AIM OF PROJECT: *To investigate the relationships that develop out of a consumers' choice and the personal, social, environmental and economic impact that choice has..*

- Work in groups of 3-4 students.
- Select a product to be researched from the following list:

Sporting merchandise	Watch	Cars
Shoes	Make up	Cardboard boxes
Wallet	Perfume	Paper products
Medication	Soft drink	Stationary
Shopping bags	Electronics	Clothes
Toys	Appliances	Other

- Use research skills (See Information Literacy posters in classroom) to investigate your selected product.
  - What is the relationship between production of the product and the environment?
  - What is the relationship between the production and how it effects individuals and communities?
  - What is the relationship between the product's function / use and the environment?
  - What is the relationship between disposal of the product and the environment?
  - What is the relationship between the purchase of this product and the economy?
  - (Question generated by group)
- Your research needs to be presented in the form of (at least one of):
  - Film/Podcast
  - Picture sequence
  - Poster
  - Powerpoint presentation
  - Newspaper/ magazine
  - Diorama
  - Model
  - Picture Book/Brochure
  - Interactive demonstration / experiment
  - Report
  - Quiz
  - Board game

An example of a project as designed by the teachers and students of level four.

The skill that scientific literacy has brought into this aspect of project development is that the students are able to be critical in their thinking and questioning. They are also able to be reflective and responsive to questions posed by others and act on them in a constructive way.

> *We go away and do our own investigation, mixing with other classes. We don't have to be writing, we can use the computer, we can read books, we can investigate some different sorts of things, and … I kind of like it, actually. It's a bit more independent. You don't rely on the teacher as much for help, you just continue with whatever you're up to. The teachers are kind of guiding us, but we are leading the way. They show us ways that we can find information for the topic. The teachers give us a guide on the right things to learn, and if we stay on track answering our focus questions then we are doing the right thing. (Saskia, Emma, Hannah & Elisha)*

The presentation of the inquiry is an element that is a major focus. However, the students are instructed that the research is to be their initial priority when setting timelines. This has been something that has improved, on both the part of the students and by us as teachers because it seems to be a natural instinct for students to want to move straight into this element if allowed.

When selecting the modes of presentation we leave it very open for the groups to choose. Many contemporary and traditional ideas are modelled for them and without fail students always manage to find new, untried modes of presentation to share with the group too. There are several reasons that we are not prescriptive about the way that students present their work. Firstly, it allows for students with particular interests or skills to shine. It also means that during the presentation process there is greater interest in viewing many different projects. One other reason is that different topics lend themselves better to being presented in different ways. One thing that we make sure we do is to value the number of presentation modes differently on the assessment rubric ensure that each group varies their presentation styles.

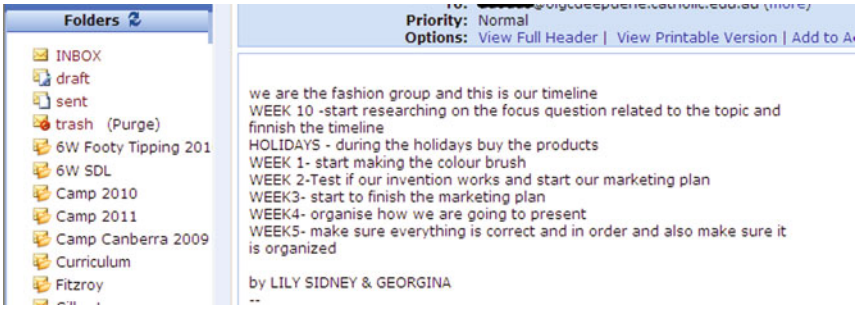
OPENING THE LEARNING TO PARENTS

At our school in the past couple of years, a new practice has been to invite parents into the classroom during "multi domain open sessions." This has been an important part of our work where the children get to either model and talk about their work to their parents and others who come to look if in progress, or they have the satisfaction of showing off their finished work if they happen to be there for the presentation.

It is important for parents, and others in the community for that matter, to see how scientific literacy is impacting the learning of our students. It gives them an understanding of the change in the teaching of science in the 21st century where students are learning to make educated decisions based upon their knowledge that it will have some influence on everything happening around them.

At the start we send an email to the teachers to check. That was good because the teachers would ask if we had completed what we said we would. Most of the time you do complete it, but sometimes you don't, but that's ok. (Georgina)

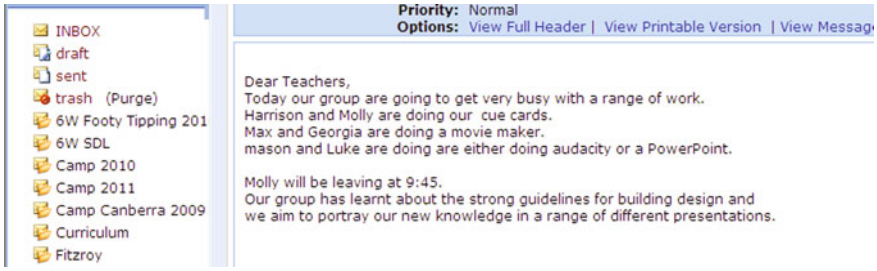
Another initiative that we have trialled this year along with a focus on scientific literacy and student directed learning has been for students to be accountable for their learning. On my recent trip to Christchurch, one of the strategies that I witnessed was senior students using Google calendars to inform their teachers, parents and classmates of their intended learning for each day. In discussion with the teachers and students that were involved in this I heard many positive reports about the effectiveness of the process. Students had to have an awareness of their own learning needs, they were focused on timelines that had been set, there was documented evidence of the work that they were doing and it was they who were accountable - to both teachers and parents.



Upon discussion with other teachers in my level, we decided that it seemed like a process that our children would be capable of, albeit a modified version. The students in our system were using individual email accounts, provided through SINA, so we didn't have all of the features available through Google calendars. Instead we made the modification of simply emailing the teacher at the beginning of each session to convey the relevant information. We made sure that a process was set in placewhere students would spend several minutes in a meeting with their group, discussing those tasks from their timeline that needed to be done and who was going to be accountable for completing those tasks. They would then be required to forward an email to each of the three teachers with specific details outlining their plan for the session.

The feedback that has been given by both the students and teachers on this process has generally been very positive. From a teacher's perspective we go into each session knowing that there is a greater sense of focus for all of our students and that we do not have to spend as much time asking students what they are up to and ensuring that time is not being wasted. Similarly, there is a sense of focus from the point of view of the students. It gives them greater direction and responsibility to achieve. There has been good feedback by those in the groups that are seen to be the leaders that they are not left to do most of the work because all group members

are required to openly take on different roles and responsibilities. Even those students who might in the past have been unsure of what to do, have shown pleasure in the greater sense of independence through this process.



THE IMPORTANCE OF BEING EXPLICIT

Science is in every subject, but we don't really realise it. (Georgina)

One important thing that I have learned in the process of incorporating scientific literacy into our multi domain approach is the need to explicitly state the type of learning that is going to happen, subject wise. This understanding was something that I stumbled upon inadvertently in conversation with some of my year 6 students a couple of years ago.

A group of girls had come back from their (soon to be) secondary school where they had just spent a lovely day of orientation, meeting some of their new teachers, finding out their classes and being introduced to some of the new subjects to which they looked forward. It was all a buzz of excitement and then the conversation went along the lines of, "and it's really cool, we get to do geography, history, science …"

At this point I stopped the girls, as I just had to ask them what they meant. They were looking forward to all of these new subjects that they didn't do in primary school. It was only when we went on to talk about the work that we had been doing that they had their "aha" moment.

Lesson learnt. For not just the girls; but for myself also. Explicitly stating the subject content is important for the students to see. When you do this, and the scientific literacy is embedded in your teaching well, the students grow to understand the value of its purpose.

UPON REFLECTION

Scientific knowledge is great, but unless our students are able to identify its existence in the world around them, analyse it, critique it, challenge it, and change it, then what impact can they have on it? The understanding of scientific literacy held by the students of 6W and myself is especially similar in one element– science is continually evolving and improving. I hope that our experiences give a clear vision of how scientific literacy can be evident in a multi domain approach to the curriculum. It has been an enjoyable professional journey that has broadened my teaching and enhanced my students' learning.

Anthony Walsh is a Grade 6 teacher at OLGC.

STEPHEN WALSH

10. BUSTING THE MYTHS ABOUT SCIENCE TEACHING

I admit it. I am an avid viewer of the television series MythBusters and have been for years. Each show tries to bust or confirm certain myths concerning a diverse range of science-rich concepts.

> Can enough duct tape, when tied around a car and to a pole, force the car immovable?
>
> Do corks inside a baseball bat improve its potential for the ball to be hit further?
>
> Is the toilet seat really the dirtiest household object?

Naturally, being a television show, there is an element of tension and theatre involved in each experiment. However, MythBusters clearly follows a line of scientific investigation, making predictions, testing, observing and tallying results and then concluding with an outcome.

When I first began watching the show a few years ago (before the Scientific Literacy Program began at OLGC), I did so purely for entertainment purposes. I do not consider myself a 'science-genre devotee' by any means. However, I have learnt that although MythBusters is a science-based series, I can understand and interact with it because it is more focused on scientific process and less on content. I find it impossible now not to critique the show.

> Were they as consistent as they could have been during the testing process?
>
> Why didn't they use a more diverse range of materials and pay more attention to replicating conditions to make sure the experiment worked?
>
> Why were they so quick to jump to their conclusions?

As I learnt more about good science teaching and learning through the scientific literacy program, I became more aware that scientific literacy is underpinned by asking good questions, developing critical thinking skills and understanding the considerations involved in the design and implementation of a scientific investigation. These were areas in which I found myself improving, evidenced in my own interactions when watching MythBusters.

By improving my own awareness of the skills needed to be scientifically literate, my confidence in science teaching grew. I developed a strong sense of what the students in my class could achieve. Although I might not possess a large amount of

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 93–99.

science content knowledge, I have become more confident that I have the skills to be a good science teacher. The myth that in order to be a good science teacher, you require all the content knowledge is busted!

THE BEGINNING OF MY OWN SCIENTIFIC INVESTIGATION: I NEVER WOULD HAVE PREDICTED THIS...

At secondary school I completed my 'last science lesson ever' with glee at the end of Year 10. In my first year as a full time teacher I felt nervous about teaching science due to my lack of confidence in my knowledge about science teaching and learning. As a result, I shied away from teaching it in any meaningful way. But there was one event at the end of my first year that led me to question and transform my thinking: the beginning of the Scientific Literacy Program at OLGC. Here I was sitting in a whole-school Professional Development session after what had been a long, tiring and busy year. Ordinarily, a typical graduate teacher might drift off in thought about trip plans, work out the best way to make the most of the holidays or even just watch the clock tick by. However, I found myself listening intently. The notion of 'scientific literacy' was new to me and I did not have any idea of what it was or how it could work in the classroom. But I found myself wanting to know more.

Simon Lindsay (from the Catholic Education Office in Melbourne) encouraged me to begin the process of debunking the myths in my own mind about how science can be incorporated into the curriculum, by encouraging all staff to make the most of serendipitous moments – that is, making links with the science in events or issues happening 'then and now'. I may not have predicted it at the time, but following this way of thinking about science teaching and learning allowed me to take a more flexible approach to planning, ensure that student learning was kept real and current, and the process was student-focused and one of discovery.

TESTING THE WATERS

Early the next year, influenced by discussing, questioning and reflecting on scientific literacy with other staff members, I noted that I was beginning to see its connections to Maths, English and other areas of the curriculum. I was not sure what scientific literacy actually was, but I could see it as a way of using and developing critical thinking skills; many of which are not limited only to science.

I used this new approach to thinking when I asked the students in my Year 2 class what they wanted to learn about during the unit, Sustainability. At this time our state was experiencing extreme drought conditions. There was constant discussion in the media regarding tough water restrictions, the level of available water in the catchments, water-saving practices at home and looking for alternative ways of providing safe drinking water. Perhaps influenced by these issues surrounding them, the students told me they wanted to learn about "water conservation". Their choice then created a very relevant context for our unit.

Using the serendipitous moment speech as my inspiration, the class and I tracked dam levels from the daily newspaper, updated the results on the whiteboard and

read scientific-themed guided reading texts. As we delved into the unit, the students surprised me with their level of questioning:

What are desalination plants and can they help?

How is water clean when it gets to us?

These questions appeared to be very complex and I was beginning to feel inadequate in my own science knowledge. There was a temptation that I needed to answer these questions for my students, even though I wasn't really sure of the answers! Like many teachers, I felt I needed to have to the answers in order to appear to be in control. Allowing the students to follow their own wonderings had led me to a place where I was not expecting to go, nor was I completely comfortable.

Despite my feelings of uneasiness, I persisted. With OLGC's critical friend I developed a series of lessons based around water filtration and the connection between water in river systems and habitats. The students came to understand the importance of clean drinking water and that their choices can have an impact on the quality of water in river systems. They compared the availability of fresh drinking water with that in other, less fortunate countries and made connections with a platypus trying to live in a polluted river system.

Had I not allowed the students to explore their initial wonderings, the learning would not have been as rich. I was able to bust another myth. I realised that the best teaching practice was to model myself as a learner and change my role to a guide or facilitator rather than being 'the one with the answers'.

At this time, although my science teaching was developing, I was a little frustrated with the lack of 'hands-on' experiments in the classroom due to what I saw as limited resources and time. I felt as though doing experiments was so important to science. Perhaps this was because of the way I had been taught science, particularly at secondary school (even though I became disconnected from science as a result)? Perhaps it was due to the importance given to experiments and hands-on tasks in my teaching course at university? Or perhaps it was due to the fact that experiments seemed to be a sure-fire way of getting students engaged in a topic? Of course, I had heard the myth from the scientific literacy program that simply doing experiments does not build on the scientific literacy of the students, but I wasn't convinced and needed to see how and why this was possible.

At the same time, I was also frustrated that our Sustainability unit was not as coherent, flexible or as inquiry-based as perhaps I would have liked it to have been; the unit had followed on from what we planned at the beginning of the term, rather than continuing to build on and enhance the knowledge the students were acquiring. These were two areas of my own science teaching I felt I needed to address.

STARTING TO SEE THE RESULTS

Throughout the following year I underwent extra Professional Development through the Science Teaching and Learning (STaL) program. This program enhanced my knowledge of science teaching and reinforced many of the things I had heard about during the Scientific Literacy Project at OLGC. I could see that my understanding

of scientific literacy was growing and I was shifting away from thinking that hands-on experiments were paramount to good science teaching. My goal at the STAL program was to become equipped with ways in which I could get my Year 2 class to see science as more than just experiments or 'bubbly science' as they called it.

From all the possible tools introduced at STaL to enhance scientific learning, the one I felt most confident about implementing in my Year 2 classroom at OLGC was a Question Wall for the start of our Change (Weather) unit. The students asked a question they were wondering about and they, or anyone else in the class, could research and answer it. Their questions allowed me to see the levels of understanding and alternative conceptions in the class, and provided valuable feedback for me as to where I could go with the class.

After preparing their questions and posting them on the wall, the students were able to classify their questions into categories such as rain, wind, natural disasters – a process in which they were thoroughly engaged. In fact, some students went home and researched the answers that night! However, for me the emphasis was not so much the answers to the questions, rather it was an opportunity to teach the class about the journey of discovery and the scientific notions that were applied (Walsh, 2010).

During the Weather unit we also predicted daily weather, researched the Bureau of Meteorology website (2010), collected our own data using weather patterns and covered content through science texts and discussions. Interestingly, I found myself focusing as much on the skills (questioning, researching, following a scientific investigation, connecting with the real world) as the content we were studying. Over the course of a year, the Year 2s were beginning to understand that science was a method of study as well as an opportunity to discover new things – not just a time for experiments.

Had my students been deprived due to (perceived) lack of time, resources or hands-on experiments? Or had their scientific knowledge actually been enhanced by the approach we had taken? Perhaps the change in approach helped to shift the students' thinking towards a more complete understanding of science? The myth that experiments are all-important in developing scientific literacy was also busted!

During 2009, the OLGC staff were beginning to develop a more on-going approach to science learning. We were trying to build on the learning achieved over the course of a year through making science-related links between units, rather than finishing a unit at the end of a term and moving on to a completely new unit and area of learning, as had previously been the case. When we first trialled this approach some of the links between units were a little forced and led more by our critical friend than by the teachers themselves. At least, I know that it was a challenge for me initially to think about linking units in this way. The traditional approach (or myth) of teaching a unit and then moving on was a hard one to break. After all, by the end of a term, very often everyone (including the teacher) is happy to move on to something different!

Over the course of the year, the teachers in our level (Years 1 & 2) developed our skills at linking units, with varying degrees of success. A challenge for me was feeling that the units were not ordered in a way that would necessarily lead into the

next unit (units were not designed or created with this in mind). For some units such as Sustainability and Technology, finding the science concepts and links between them were easy. However, for others such as Diversity or Change, where our thinking more immediately moved towards the possible Humanities concepts and links, this proved more of a challenge.

With the help of our critical friend, the level 2 (Years 1 & 2) focus for the term 1 Diversity unit explored diverse environments across Australia (such as desert, rainforest, city, bush and coast) and how certain flora and fauna survive in each environment. The students demonstrated their learning through dioramas. In order to link the next unit of Change (more specifically, weather), we began by looking at the weather in these different areas. Far from being more of the same, this was structured learning that had purpose and provided a great starting point for the students and the staff.

OBSERVING THE JOURNEY

My confidence in teaching science continued to grow. At the beginning of 2010, for the unit of 'Relationships', my Year 4 class focused on how all living things are dependent on forming relationships for their survival and continued existence. The students were able to investigate the relationships of one of five animals – dolphins, elephants, weedy sea dragons, orang-utans and bees. This learning led directly to the second term unit, 'Sustainability' and the study of endangered animals (with strong links to the impact of Palm Oil on orang-utan habitat).

From the beginning of the year, our level team (Years 3 & 4) was not merely discussing learning outcomes for term 1, but also, how we could link units. At that early stage we even raised possibilities for how we could link the term 2 and 3 units! By no means were we locked into specific unit understandings from the outset, but we were thinking of the skills to be developed over the course of the year and ways in which this could be achieved. This reflected a major shift in our thinking and attitudes to planning units.

My personal goals were to further improve making the most of serendipitous moments and creating an exciting and engaging classroom. Over the Easter holiday period, I travelled to Tasmania. While I was there I visited the Tasmanian Devil Conservation Park, with the pre-conceived idea of using this visit as an initial point of discussion on our new unit on endangered animals. What began as a slideshow of photos of Tasmanian Devils and information that I had collected, quickly turned into a discussion about endangered animals and the different ways animals could become endangered. This was the direction that I had hoped the discussion would take. However, the discussion then shifted to solutions for the spread of the Tasmanian Devil facial disease – something I had not anticipated. I facilitated the discussion, and held back from putting forward my view:

> Why can't we just move the Tassie Devils without the disease to the mainland?
>
> No, you can't do that because then you might have other problems, like other introduced species have caused.

> Wouldn't the problem just start over again there anyway?
>
> If they become extinct, can't we just bring them back to life? I've seen them do that on TV!
>
> I don't think that this disease was the fault of humans so isn't it just the natural order of things that they die out through natural causes?

I could not believe that in Year 4 we were discussing Darwinist notions and exploring ethical questions as well as scientific ones! The thinking skills required for this term would have to change. This incident once again highlighted to me the importance of not thoroughly pre-planning units and being open to a serendipitous moment. In following through this unit, the students focused on the literacy of evaluating and reviewing information – can they trust what they read? What scientific fact or evidence is used to back up research? How and why does bias come into play? Exploring these questions shows sophisticated learning for Year 4s and not limited to science learning.

Perhaps it was because I was teaching a higher year level that I felt more comfortable tackling these more challenging aspects of learning, or perhaps it was that I was more confident in my own science teaching, but I felt I was deliberately looking at ways of structuring classroom literacy differently. For example, when the class returned from an excursion to the Melbourne Zoo, instead of asking the students to write a recount of their day as would normally be the case, we instead wrote about, "A Day in the Life of a Melbourne Zoo Keeper" to make links with science in the community.

The students wrote about the importance of keeping pH levels of water consistent, due to the fact that the seals could not come out on display due to the levels not being right. Mali, the baby elephant and star attraction of the zoo at the time, had several of its keepers lining up to be asked questions about their role and thus, the students also included their information. I had not necessarily planned for the students to write about this when we embarked on the excursion, but changing the task in this way allowed the students to consider the science in their experiences on the day and led to richer reflections. Using our initial discussions as my driving force, we linked the literacy of writing expositions with the ethical and scientific dilemma of whether we should have zoos at all. Students used their own experiences and research from various resources to back up their arguments. The students were able to critically analyse the issue and reflect on related scientific issues such as conservation, animals in captivity and habitat destruction.

The Melbourne Zoo-led 'Don't Palm us Off' campaign which raised awareness to label the use of Palm Oil in food products, allowed students to look beyond the traditional role of zoos and take action themselves. This was a real issue happening around them – a great example of using a serendipitous moment to enhance learning and engage students. Students were able to make an informed choice about the issue, after critically evaluating some research on the issue. Some students across the Year 3/4 level collaborated in their own time to create websites, develop an awareness campaign for students in other year levels, design brochures to hand out and create a logo which could be attached to packaging. The students saw themselves

as being able to make a difference in what they perceived as an important issue to them. This was scientific literacy in action.

OUTCOMES FOR THE FUTURE

None of the tasks outlined above (based around Sustainability) are necessarily new, however, it is the structure of the scientific literacy program that leads to more science-rich learning in the classroom and therefore, more scientifically literate students. During the term, the majority of literacy time was devoted to developing skills essential to preparing discerning citizens for tomorrow. Such citizens are able to make informed choices about a range of science issues, become critical thinkers, look at issues from a global or communal perspective and understand the possible methods of scientific investigations. These are the skills that are imperative for students with which to leave school so they can understand and take part in the ever-changing, science-rich world around them. Of course, few of these students will become scientists by profession, but they will all need to be scientifically literate as part of their everyday lives.

The myths that teachers have about science teaching and learning can hold us back from what can be achieved. Perceived limitations – such as limited time for teaching science, limited resources or equipment for completing hands-on experiments or limited content knowledge should not define us as primary science teachers. Revising the role of the teacher from being the one with answers to a facilitator or lead learner is crucial to beginning the steps towards developing good science teaching practice. Ensuring a flexible approach to planning and classroom practice as well as making learning real and contemporary are other essential stages. Above all, providing students with the opportunities to develop life-long skills in scientific thinking and methods will enable the myths of science teaching and learning to be 'totally busted'.

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Stephen Walsh is a Grade 2 teacher at OLGC.

ANN FRANCE

11. SPEAKING ABOUT SCIENTIFIC LITERACY

Over the last couple of years I have been concerned that the move to focus on the multi domain approach to teaching and learning has been to the detriment of teaching literacy at our school. It is with great satisfaction then that the introduction and progress we have made in the area of teaching Scientific Literacy has recently reignited the need to teach the speaking and listening skills of the literacy program.

As I am the literacy coordinator in my school as well as being a Prep teacher, I think that it is great to see the speaking and listening component put first on the learning agenda for once. We know that reading (and writing) "float on a sea of talk" (Britton, 1970, p. 164). So too does our thinking process and capability of making good decisions. Promoting scientific literacy as an outcome for our students has provided a rich and powerful context for the development of these language skills.

WHAT IS SCIENTIFIC LITERACY?

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

As a teacher I am hopefully beginning my students on a learning journey that will never end, a journey that requires them to believe in and value the relationship between learning and living, where they see the need to make informed decisions, the need to know more about their everyday world, the need to become empowered decision makers. They must never be afraid to change their minds!

Our Victorian Essential Learnings state that "The fundamental goal for science education is to stimulate, respond to and nourish curiosity, wonder and questioning of the world in which we live" (VCAA, 2009) This is what we want for our students, we want them to be equipped to take an active part in their world. Scientific literacy is so important for human existence on our planet.

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 101–109.

DEVELOPING SPEAKING & LISTENING SKILLS

I believe that oral language skills hold the key to scientific literacy, and this is particularly true in the early years of learning. Students need to be able to discuss their opinions and have others agree, add to or disagree with them. But what comes first? Does oral language assist with scientific literacy or does the approach of teaching scientific literacy assist oral language development?

As a Prep teacher (first year of Primary School, 4–5 year olds) it became obvious to me that to develop effective scientific literacy, the students have to be exposed to and taught the basic techniques and norms of social interactions with others (and it definitely can be done in the junior classes). I now see that teaching for scientific literacy requires me to utilise and build on literacy teaching conventions and develop my students' skills of speaking and listening. I use the time and activities of the literacy timetable block, to create authentic reasons for students to talk and exchange their thinking about big ideas such as sustainability or relationships. My students are becoming critical and empathetic listeners and learners. They are listeners that are active, working through constructive processes to make meaning of information.

One activity that my class undertook was to break into groups of 3 or 4 and spend time talking about different pictures I had found which related to our unit of study on 'safety'. The students would select a picture and then aim to give reasons why this image was connected to safety. The other students would ask questions to gain more information, or justification. The students would then be required to write about what someone else in their group spoke about. Sometimes the rest of the class

arranged themselves as a 'fishbowl' formation (as seen in the photograph below) around one group to critique them on social skills or gain more information about the unit. These times provide opportunities for *Relevant, Challenging and Purposeful Communication*.

I always find that if the students can critique and question each other it is far more beneficial than if I do the talking. I frequently use the 'Think, pair, share' technique to generate ideas and theories about our units of study.

Just recently I asked the students to think about our new learning spaces in the school. I asked them to reflect on the safety concerns, if any, that we may encounter in the future in our new science room, library and office. My Prep students were able to come up with some realistic safety issues about these spaces and I then placed the students into teams to investigate the issues further. This simple strategy became the beginning to a fabulous gathering of data through observations, interviews and surveys. (My Prep students hope to use this evidence to form a protocol about how to use our new areas safely, which will be presented to the school's Student Representative Committee (SRC) and later to the school community in general.)

THE CONFIDENCE TO HAVE A GO

As with the teaching of all subject areas students in the first years of schooling need to be exposed to opportunities which allow them to have a go at something new, they need to see models of what this learning looks like in action and most importantly they need to be encouraged to have a go so that they may become independent learners themselves. At this early stage much of their learning needs to be teacher directed and closely monitored for development. These are the foundation years of learning and the foundation years for scientific literacy.

Once Prep students have established some of the norms of social interactions and effective group discussions, such as how to listen to others, to not just repeat an idea but take part in a conversation, then you are almost guaranteed an interesting and often explosive discussion. Prep students have little to no inhibitions about what they say and think, they are like mini scientists taking part in discussions that can explore and hypothesise about a topic or an issue.

Sadly I think in my first years of teaching I was probably guilty of missing opportunities to witness such fantastic discussions. Like many teachers I may have contributed to a belief that there is only one answer that will make the teacher happy. Students learn to become compliant and respond accordingly. However, I think it is crucial that I encourage my students to be independent learners, to take charge of their own destinies, their own thinking and their own opinions. To do this I had to take a big step back and share intellectual ownership with my students and allow them to explore, hypothesise and find things out for themselves, even prove themselves wrong.

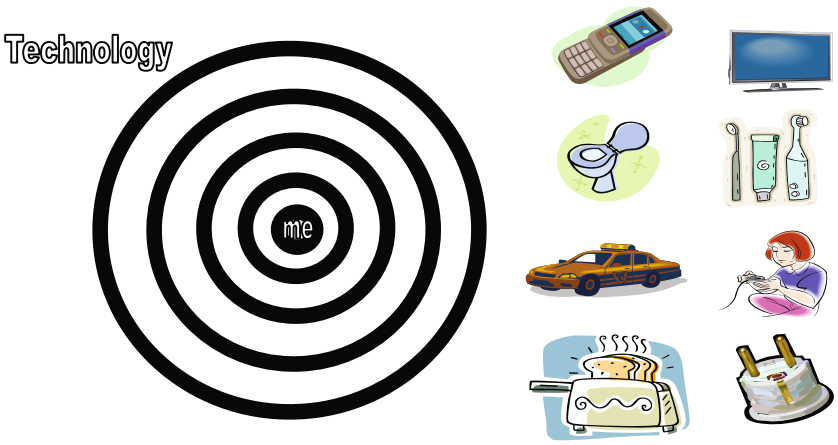
During a discussion in a unit of work on 'Change' I recorded students' ideas about animals and how they change within their life cycle. One child commented that he knew about the life cycle of a frog and reported that tadpoles become frogs. One child said that first the tadpole begins as an egg. Many students in the class laughed at the idea of frogs sitting on eggs and waiting for them to hatch like chickens. Many students discarded the idea and moved on. Later in the term we visited the zoo and found out about frogs and eggs were discussed as part of the lifecycle. The students were full of knowledge about the egg becoming the tadpole and then the frog. I reminded them of their comments at the beginning of the unit and they could not believe their own previous thoughts. It occurred to me how quickly children develop their ideas and move on in their learning. It was important for me to remain impartial to their suggestions and allow them to find out about their world but I believe that it is also equally important to encourage students to reflect on their own learning process.

This year in my Prep classroom I have used the same four tuning in activities for each unit of work every term. We always begin with a brainstorm activity whereby students speak and I record whatever they know about the concepts being investigated, such as Relationships, Sustainability, Technology and Safety. I have found this to be an effective tool and something to refer back to as the learning continues.

We also use a graphic organizer which in diagram representation places the student at the centre of the page and their connections to each concept flow out from them. At the end of our tuning in time, we always put together a definition in their words. This is dated (and amended if necessary) during the unit of study and as the year continues. In time students become quite independent with these activities because the process is recognisable and familiar to them.

During each unit of study, I asked the students to construct a 'ring of familiarity' based on each topic. The students would be given 8 or so pictures of things related to the concept and place them on a series of rings according to how much each idea affects them.

Due to the fact that our rich concepts in each unit have been linked to learning in the next unit, we kept such charts and definitions accessible to help with developing further thinking.



THINKING SCIENTIFICALLY

Encouraging students to justify their thoughts and responses is an important aspect to thinking scientifically. The other day my students were working in pairs using magazines to locate images to do with the concept of safety. When they had collected their images they were required to make a class circle and report back to the group about their choice and how and why it related to safety. They openly agreed and sometimes disagreed with the reasons for each others' choice. (Relating any topic to the students themselves is the key to encouraging a passionate response with Junior students. As any Prep teacher is reminded on a daily basis, it's all about them!)

At the beginning of our unit on sustainability my Prep students really struggled to create the initial brainstorm about this concept. By the end of our unit of work

they were going home and interrogating their parents as to what cleaning products were being used around the house. One student's mum reported back to me that he had returned home the previous day and asked, "Mum, do we use animal friendly products to clean the house?" She said he was not satisfied with her positive response but made her check the cupboards with him. The importance of parents reporting student progress cannot be stressed enough. If their learning is to enable them to live well in the world then our assessment of their progress must go beyond the classroom.

What I see in a Prep classroom is what we will hopefully begin to see at all the levels; students making real and passionate connections to their learning. Happy to hypothesise and change their minds alongside teachers who encourage them to explore further and remain impartial to any opinions and ideas formed.

MAKING EMOTIONAL CONNECTIONS AND DEVELOPING A STYLE OF THINKING

During our planning sessions for multi domain, I have raised the idea of 'active thinking'. I believe that thinking scientifically means being an active thinker. Students must be forever questioning, looking for evidence and forming opinions about what they see and hear in life, as opposed to passive thinking where students are happy to take on whatever they hear as gospel. I can tell when a topic is 'off the ground' when active thinking begins to occur.

Our whole school was working on a topic of 'Sustainability' and my Preps were happily working through the sessions but my concern was that I couldn't see active thinking happening. They had not connected scientifically with this unit of work. I raised this issue with our school's 'critical friend' and she suggested a scenario that might connect my students with the unit of work.

We began to focus on the sustainability of a platypus living in a river that was becoming polluted as a consequence of the impact of modern living. The students made an emotional connection with the cuteness of this little creature and began to develop feelings for its protection. The students sat in a circle and cuddled and stroked a soft platypus stuffed toy while brainstorming the facts they knew about this animal.

Using visual aids I began to tell the story of a platypus trying to find a burrow to live in within a river that was slowly being polluted by our modern world. The students were able to add similar pollutants to a bowl of fresh water and before their eyes a bowl of polluted water appeared. Water that they certainly did not want their cute fluffy little platypus to live in!

They started to question why the river was polluted and then investigated how they could change their own lives to protect other animals. They began to think actively. Students began voicing their opinions about the safety of the platypus

If I met a farmer I would tell him to stop using dangerous chemicals that can spread into the river. (Charli)

I think that farms should not be allowed to be close to rivers in case their chemicals or animals destroy the rivers. (Jacquie)

Next time we go camping I'm going to ask dad what he does with our rubbish. (James)

When dealing with students in the junior years I believe you have to appeal to their emotions. They really have quite strong opinions about things once you can uncover that emotional trigger. Students that had not even heard of the word sustainability were 5 weeks later asking their parents to check the kitchen and bathroom cupboards to make sure they were using animal friendly products.

DEVELOPING AND CAPTURING CHANGES IN LEARNING BEHAVIOURS

In my opinion an important component of scientific literacy is about taking action due to formed opinions and changing people's behaviours in order to make a

difference in their world. More importantly it is also about changing not just behaviours but thinking. I believe it is important for students to develop a thinking process that: values others opinions; questions others opinions; and, requires each student to make an opinion of their own after much active thinking. Not to forget being able to change their opinion if necessary.

The world in which my students are living and will work in requires me to teach them to become active thinkers when faced with television commercials, print media, billboard advertisements and so on. During our unit of work on Sustainability, I showed the class a current television commercial for cleaning products that showed people using aquatic animals to clean their houses. It was a deliberate tug on the heartstrings and was a perfect catalyst for a great discussion about finding the meaning in advertisements. Initially my Preps thought that the animals were really being used to clean the toilet, shower etc., but after much talk we found the true message together. It is vital to switch on their thinking and encourage them to ask questions of how, what, when and why about the world in which they live.

This change in behaviour and thinking not only pertains to my students but to me as their teacher and co learner. Over the years working within this scientific literacy project with Monash University, I have drastically changed the way in which I teach and plan; not only for science and multi domain but for all subject areas. The level of professional dialogue that now takes place at our school is remarkably different to previous years. I see the need for much talk with my colleagues and students about the direction in which our learning will travel. Formal and informal planning sessions are necessary as is the attitude within the classroom. The ideas of letting students discover and investigate things for themselves, of remaining impartial and to encourage thinking to begin is crucial. If I expect my students to change and become scientifically literate then I must change first.

CHALLENGE FOR THE FUTURE

I think my next big challenge is to try to capture this development for assessment purposes. In my teaching in the area of assessment and evaluation I try to recognise that students may represent these changes in their own thinking in many different forms. I find that it is essential to record students' ideas with brainstorms and various graphic organizers at different times throughout a unit of study. I also permanently have a flip camera available to capture the rich discussions that take place. However, I am constantly wondering if what I am recording and assessing is sufficient. I am now very aware that assessment is not something you do at the end of a unit of study but constantly in order to move students forward. The idea that a unit of study ever ends is a weird thought too.

I began this chapter by saying that I wanted to encourage my students to become life-long learners so it therefore compels me to ask whether their study in the area of 'Sustainability' for example, will ever end? Hopefully not! The implications of making my students 'scientific literate' are huge and will require continual 'active thinking' on my behalf.

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Ann France is a Prep. Teacher at OLGC.

SECTION 3:
REVIEWING SCIENTIFIC LITERACY

JOANNA KAKOS

12. YOU DON'T KNOW WHAT YOU DONT' KNOW

So, what is scientific literacy? What does it look like? Is it different to science in the past and if so in what way? Do you have to love science? Do you have to be good at science?

Science teaching is often seen as some form of traditional concentration on the process of explaining phenomena scientifically. From that perspective then, for students to be 'judged' as being fully scientifically literate they need to be able to recognise science problems and be able to interpret the findings in the context of the real world. So it is not hard to see how scientific literacy could be understood as comprising mostly knowledge about science and the ability to offer scientific explanations. But I think scientific literacy is more than that and as a new member of staff entering into a school that had a scientific literacy focus, my experience has been challenging and inviting as I have come to see scientific literacy in new ways.

MY BACKGROUND

I am a classroom teacher. I'm not a science teacher but over quite a few years of teaching I have had the added role of Science Co-ordinator and then in the latter years a position of leadership in science. The reason I took an interest in science was not that I was exceptionally great at science, but I have observed that science and the teaching of science in primary schools was often an area of neglect and I felt a need to do something about that.

I think that science is the area which gets left out of the curriculum in many primary schools, or, if apparent at all, it often falls victim to a series of special lessons and/or experiments. This way of seeing science in the curriculum can be put down to the idea that some science is better than no science and unfortunately in an already overly crowded curriculum where the primary focus is ensuring that children are literate and numerate, the status quo of a series of science lessons, experiments, incursions and excursions continues to prevail.

Am I being critical of how I have observed and experienced the teaching of science in primary schools? Not really! I think that what happens is we do what we believe to be effective within the time constraints of our teaching programs and within the limits of our expertise. As educators though we are obliged to continually search for ways to improve our teaching in order to enhance the quality of our students' learning.

Many years ago I was involved in a local council project. The aim of the project was to develop a Secret Garden at the local Arboretum. There were four schools

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 113–118.

involved in this project. The Secret Garden was to form the centre piece of the Arboretum. The schools were involved in the entire process from designing and constructing at the school level, where the students generated ideas and learned specific skills, which were then applied to the Arboretum Secret Garden. The many people involved in this project included: the students; schools' staff and parents' committees; various education department services; the local council; businesses associations and individuals. Through this very rich project students were highly engaged and the science learning was meaningful and relevant and that is often what is then seen as real science in schools.

The Scientist in Schools Partnerships has been another rewarding venture which has enabled tremendous science teaching and learning opportunities to be made available to students. One such partnership which I was involved in was investigating a lake in the local environment. In partnership with the scientist we investigated many different aspects pertaining to the lake and its impact on the local environment. Some of the areas of investigation involved finding out about the flora and fauna in and around the lake, the catchment and flood retaining basin, the leisure and educational activities at the lake as well as learning about the Wurundjeri people. Each class in the school took up a specific area of interest for their own investigation. The project was very engaging for all concerned. However, to my surprise at the time, there were still some grades that could not find the time to be involved in the project.

I have attended many Science Professional Development Days where teachers have presented various projects from their schools and there is definitely a plethora of pertinent, effective and engaging student centred science going on in many schools. My point in using these examples from my own teaching is that what it reminds me of is that teachers continue to implement some wonderful science teaching/projects where the content is relevant to the students and where the students are engaged in effective learning. Despite that, I am still left asking, "Is that enough?" "Do we engage all students in a meaningful way?" "Does our practice illustrate that science is more than simply acquiring knowledge?" "Does a unit on Space, Electricity or Living Things really impact students in ways that enable them to participate in their world in effective ways?"

Gaining knowledge of content is important, but as the projects I noted above suggest, there is also a need for students to develop skills such as critical thinking and questioning, developing new ways of accessing information – going beyond content alone. Going beyond is what I think I have been experiencing at OLGC.

THE PROCESS: MY TIME LINE

This is my first year at OLGC and I am still in the process of learning and developing a greater understanding of scientific literacy and how it is evolving at the school and how that plays out in my planning level and in my own classroom.

The Job Interview

When I was interviewed for a position at OLGC I was informed that the building, which had already begun and was due to be completed in the coming year, was an

Open Space-Science/Discovery/Library and ICT Area. I was really keen about the possibilities and hopeful of working there. The possibilities sounded really exciting and I thought that it was inspiring to be involved in a school that was willing to make a shift in thinking and gear implementation of curriculum towards current ideas and beyond.

To be quite honest though, I was thinking that the new science area would be a place where we would take classes for specific science lessons and where we could conduct experiments and fun science activities. I knew no other way. You don't know what you don't know!

In the Thick of Things

You know how it goes, once the year begins teachers begin chasing their tails in the busyness of teaching. So being new to a school takes time to absorb all the general routines, let alone come to grips with an idea like scientific literacy and planning using Multi-Domain Approach.

I heard the term scientific literacy bandied around the place from time to time. It certainly came up in the planning meetings and teachers referred to the Scientific Literacy Project, STaL and Monash University regularly. I heard snippets of conversations about what was involved in the project and how there was this Swedish Science Educator who had visited and worked with staff at OLGC.

My mind was awash with ideas - scientific literacy must be something if it's attracting attention from overseas and a university and the Catholic Education Office (CEO) is investing time and resources into it. Was I clear yet about scientific literacy and how I would do justice to it with my students and the school? Not really! Not yet!

I kept asking lots of questions whilst grappling with my thoughts about science teaching and learning. I was finding a need to evaluate what I believed about science, the way I taught it in the past and how this shift in science thinking (whatever that was) was actually resonating with me (or not). I felt a need to ascertain what I believed scientific literacy to be, what the school's understanding of it was and how and why it impacted teaching and learning.

What did Scientific Literacy Look Like for Me?

I began looking around the classrooms, the space and displays outside the classrooms, the atrium where there are often displays. The term one Multi-Domain unit was 'Relationships' and that gave me an insight into how scientific literacy was being developed at OLGC.

What was different and striking here was that I was in a school which took science and scientific literacy seriously. It became obvious in time that via the level planning and multi-domain planning sessions with the Head of Learning and Teaching and our critical friend, there was a whole school focus on ensuring that everyone was on the same page and that there was a common understanding. Scientific literacy was not just a term that was flippantly thrown around; it actually drove the way of thinking, planning, assessing and presenting curriculum at OLGC.

In our level planning meetings I noticed that teachers used the term scientific literacy and were aware of making relevant connections within the curriculum with science at all levels. This process made further sense to me when, during our multi-domain planning sessions with the Head of Teaching and Learning and 'critical friend', we discussed where we were headed with our unit and how best to make connections with students in ways that would have them working scientifically. The aim of this approach was for students to strive towards being contributors to society by using science knowledge in appropriate ways in order to make sense of the world.

These sessions were highly valuable in providing a forum for discussion and challenging our ideas. I now know that without these sessions I would have felt out of the loop, I would have gone off on my own and continually required help to better understand the process and the thinking involved and how I might transfer that thinking into the classroom. These planning sessions were invaluable in assisting me with this process.

On Track: Where Am I Now?

I certainly have a much clearer picture and understanding of scientific literacy and planning multi-domain units differently. The term 3 unit was 'Technology', the focus being that students would discover that developments in technology impact on, and will continue to change the world in which they live. That focus followed on from the Term 2 unit 'Sustainability', the focus being on a commitment to sustainability reinforcing our responsibility to future generations to protect and enhance the world in which we live.

In our level we came up with an outline of a project and a possible outcome. The students formed project teams and assigned themselves a project team manager. As a team they worked co-operatively to research sustainable technology, design a 2D or 3D floor plan, reflect on the process along the way via a Project Team Journal, and selected and collected materials in order to build a sustainable eco-house. As I write this chapter, we are now in the process of assessment of the unit - the students' self assessment and the teachers' assessment of the unit. On our multi-domain Day the students presented not only their finished eco-houses but also their journals with reflections of the process and their trials and tribulations of team work – learning to co-operate, making decisions, encountering and solving conflicts, each member's contributions and level of perseverance, their ability to share resources and the building social relationships.

Where to Next?

The goal of PISA (Programme for International Student Assessment) is to measure competencies that will equip students to participate productively and adaptively in their life beyond school education. With this thinking in mind, at OLGC we are working to understand and promote scientific literacy as a valued learning outcome for all of our students. As teachers we believe that this is an important focus for our teaching and learning in science as we prepare students for the 21st century.

We talk about equipping students for the 21st Century where they can engage in the world in which they live by acquiring an understanding of science and recognizing the impact it has on our society. We want our students to be critical, responsible, interested and confident participants. I believe that scientific literacy is the vehicle through which we can achieve these goals.
In PISA, scientific literacy is defined as:

> ... an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the issues of science, as a reflective citizen. (OECD, 2006, p. 14)

My reading on the research carried out by PISA has given me a more comprehensive understanding and I feel confident that scientific literacy is the way of the future.

REFLECTION

> A broad and open-ended approach to scientific literacy would free teachers and students to develop a wide variety of innovative responses to the call for an increased understanding of science for all. (DeBoer, 2000, p. 582)

Since coming to OLGC and experiencing how teachers are teaching and how students are learning through scientific literacy, I can now confidently say that it is not good enough to persist with the previous methods of teaching and learning science that we are all so familiar with. Changing the way that we think about and implement our practice is no longer an option but a necessity in doing justice to our students.

It is a necessity because it encompasses science for all and not just preparing a future generation of scientists by focussing on content-based science teaching and learning. The multi-domain approach at OLGC facilitates an integrated approach to teaching and learning where scientific literacy is part of inquiry-based learning and where rich concepts and understandings are consistently addressed.

Being scientifically literate is about using science to enable people to understand scientific issues in the media, locally and globally. The aim for schools is to provide a curriculum which encompasses all students in order to help them become scientifically literate - not just those who have an inclination towards becoming scientists. Another key factor must be the development of a positive attitude and self efficacy of students as science learners with a responsibility for seeking to understand science-related issues.

This is not and should not be any different to the expectations we have of students in literacy and numeracy, where we encourage them to believe in their own capabilities. When this is the case, students are more likely to be engaged and seek learning for a purpose. Interest, motivation, enjoyment and engagement are important aspects of student learning in all disciplines. It is our role as educators to ensure that students are operating in that way in order to maximise their learning.

SCIENTIFIC LITERACY: A SHIFT IN THINKING!

So what are the implications for teachers embarking on this scientific literacy process? What is required for teachers and students to become successful partners in learning for the 21st Century?

I believe that we need to empower our students to be scientifically literate. If that is the case then students will be given the opportunity to be empowered in their process of life-long learning and to: understand, appreciate and gain new perspectives on issues in science that influence their lives.

Our responsibility as educators is to equip our students with the thinking tools to form opinions, to evaluate critically and to make informed choices, in order to participate fully in society and the world in which they live. Scientific literacy is about equipping all of our students with the necessary skills for obtaining information, the vocabulary and thinking processes which will enable them to use science in a broad sense rather than just doing science in a narrow field of expertise such as biology or geology. Therefore we need to provide all students with opportunities to know how to deal and cope with the life that they will encounter in the twenty-first century. That is what scientific literacy is all about.

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Joanna Kakos is a classroom teacher at OLGC.

ROSEMARY CUSSEN

13. UNBOXING MY SCIENCE TEACHING

A Personal Scientific Literacy Journey

IN A PREVIOUS TEACHING LIFE TO THE PAST 5 YEARS...

My classroom teaching was streamlined, organised and 'boxed' into subject areas with definite time allocations. I had a reasonably clear idea as to what knowledge I needed to impart to my students, how I would impart it, (probably this meant with plenty of teacher talk and predetermined sheets and activities) and a concluding, 'finish up' lesson to the topic that may even have included a small test on student knowledge gained.

My teaching of Science topics also reflected this methodology - a box for magnets, weather, solar system, energy, matter, floating and sinking, oh and the biggest box of all for EXPERIMENTS! That's what brought my Science teaching alive for the students; I knew that, I could see it in their interest, their attention and their eagerness to participate. But the experiments were short lived, took time to prepare, and sometimes didn't work. In fact, to be honest, I didn't feel comfortable about my own science competencies to answer the questions that usually followed. So what generally ended up happening for me was that Science sub-consciously (or perhaps conscientiously) was often put on the bottom of the curriculum-to- cover list.

5 YEARS AGO ...

Perhaps the solar constellations began to move towards OLGC as I moved back into the classroom in a shared teaching position in the junior school. The school began to have Celebration Learning days in Literacy, Maths, Italian Studies and yes, you guessed it, in Science too!

I really loved those Science days when the students moved around different classrooms and experienced Science through simple experiments and activities. They were fun days, the students really enjoyed them and the teachers embraced the idea of trying to present many different facets of science, although for me it was still a boxed day of science teaching and learning with very little possibility, or intention, to follow up or make connections with what was happening in the classroom, let alone the world. But in retrospect, I think it was the beginning for me of a whole new chapter in my journey of teaching Science. The seals on my science box had been broken.

At this time some staff at OLGC, (and many more since then) became involved in the STaL project. I was fortunate that my teaching partner was in the first group

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 119–126.

to take part in this professional development and as a result, so much of my understanding of this new way of looking at science teaching and learning was done by osmosis.

As a Years One and Two team member, I began exploring the Inquiry based approach to learning across many areas of the Victorian Essential Learning Standards (VELS) curriculum. The STaL professionals at Monash were encouraging teachers to teach Science using this same inquiry based methodology and to make scientific connections within any Multi Domain unit. This was a huge change in thinking for me. I was being challenged to completely unbox my narrow way of looking at science teaching and learning, to find the Science in and across the many learning domains and to make real life connections.

My professional judgement told me that integrating science into our Multi Domain units was, at the very least, logistically sensible because we did not seem to have enough hours in a week to cover the ever broadening and demanding curriculum and it certainly was a subject area that past experience had shown me that students enjoyed and got excited about. However, I was uncertain as to the quality of the teaching program I could offer if I was to allow students to have a voice, inquire, research, follow their interests and reflect on their learning in an area of the curriculum that I did not feel so confident about.

I was hearing in teacher conversations that we needed to work towards being more facilitators of learning rather than controllers of learning. We did not need to have a unit of work completely mapped out before the students participated in the learning - in fact the idea was that they were to guide us in the direction that the unit would go, and more than likely, as I have since found out, it would go in many directions because of the various interests, skills and styles of learning that each student has.

The educational research was telling teachers that the most valuable and rich learning experiences were those where the students were involved in the decision making, engaged in interactive learning, able to build on prior knowledge, make connections with what was happening in the real world outside the classroom and had the opportunity to reflect on their learning. For someone who likes to be in control and organised I knew I was going to have to learn to be comfortable with releasing the reins a little bit. I was concerned that I did not know how to firstly, find and secondly, connect science thinking and concepts into our Multi Domain units. However I had confidence in my enthusiastic team of teachers and teaching partner and I was prepared to have a go at this ‘unboxed’ way of integrating science into the broader curriculum.

MAYBE 4 YEARS AGO ...

OLGC became a Nucleus School, which allowed our staff to be a part of a Scientific Literacy project with the professional support of Kathy Smith as our critical friend. Our Head of Teaching and Learning was also an enthusiastic and innovative curriculum leader who was able to offer guidance and encouragement to classroom teachers as we began to grapple with this new concept of scientific literacy.

OVER THE FOLLOWING YEARS...

I have had many questions and these reoccur every time we start a new unit of work.

- Where do we begin this unit of study?
- What sorts of activities are going to offer rich and valuable scientific learning within a Multi Domain unit?
- How am I going to be able to track and record student progress so that I can see their developing scientific competencies?
- What links to the community are going to help students to make sense of their new scientific knowledge and skills?

As we developed our new ways of thinking about connecting science into the curriculum, Multi Domain units were broadened into Key Concepts which allowed student entry points at all VELS levels and the development and refinement of understandings and skills as the students progressed through the primary years. This approach also opened up opportunities for shared teacher discussion across the levels, shared multi-aged learning experiences and a more comprehensive coverage of the VELS.

The VELS level teams were timetabled in order to have two Multi Domain meetings per term with our 'critical friend' and Head of Teaching and Learning. At the first meeting we discussed our key understandings for the new unit and formulated focus questions that would guide the direction of the unit. Our facilitators were able to highlight and challenge us by asking about the scientific skills and learning possibilities within the VELS framework. In hindsight, these meetings have been critical to my professional development in scientific literacy as I am guided in the skills, concepts and thinking processes that we want our students to have experiences in, if they are to understand the impact that scientifically based issues are having on their world.

We ask questions of our facilitators and each other to clarify our thoughts, and more often than not we leave the meeting with a direction for the unit mapped out but with a sense of openness to incorporating student interests and needs as they become obvious through a variety of Immersion Activities prepared by the teachers. The aim of these Immersion Activities is to whet the appetite of the students in different aspects of the unit. With further discussion and feedback from all teachers we are able to provide interest based, VELS informed learning experiences that will introduce or develop scientific understandings and skills, and community links (excursions and incursions, guest speakers, parent experts, etc.), so that the student learning is rich, interactive, authentic and has some scientific connections. Our second meeting at the end of the term is a designed as a reflective one where we discuss strengths and challenges of the unit covered, student learning and our teaching. Modifications of the unit are noted for next time and what links can be made from this unit to the next one.

I'm smiling at the moment because even re-reading this last paragraph I can see what a change in my science teaching, thinking and articulating my practice has happened through my involvement in this Project. I have surprised myself how I have adapted to this evolving contemporary way of teaching and learning science. My boxed science program has gone although not the great ideas and experiments that

were housed in the box. I have not thrown the box out with all its contents inside. It is the way that I am trying to implement the curriculum that has changed. I am still trialling ideas, having valuable teaching experiences as well as some not so successful ones. At times I feel frazzled by the busy and sometimes too noisy classroom that happens when students are interacting and engaged. These learning sessions remind me of the student engagement that was there before in the stand-alone science experiments that I used to do. However, I think the big difference now is the student engagement comes from the students being part of the learning decisions. They are able to search for and question the knowledge to make sense of it for themselves and apply it in hands on activities and in communal settings - rather than me deciding what they are supposed to learn. There is without a doubt a structure inherent in this new way of students experiencing science and I am feeling more and more that this approach sits comfortably with me!

SO WHAT DOES MY TEACHING OF SCIENTIFIC LITERACY WITHIN A MULTI DOMAIN, INQUIRY APPROACH LOOK LIKE?

There are a number of ways in which I see my thinking, planning and teaching has been shaped through my experiences. These are:

- Shared professional development with science experts and teachers to find the science in the new unit.
- Shared planning time and teaching ideas to make sure the learning experiences guide the students to find answers to their questions.
- Brainstorming with students about their prior knowledge.
- Immersion Activities that give opportunities to open up the science connections in a new unit.
- Students developing independent and creative ideas, taking responsibility for their learning.
- At times the teacher is a learner and the student is a teacher.
- There is flexibility, variety and open-ended tasks catering for different learning styles.
- Question Walls and Key Focus Questions which promote and guide scientific thinking are displayed in the classroom and are used as a reference point for teachers and students.
- Community interaction within and outside the walls of the classroom helps the students to make relevant links in their learning with what is going on in the world.
- A range of assessment data is being used, including personal inquiry projects, models and diagrams, ICT presentations, photos, video recording, personal reflection tasks, graphic organisers, etc.
- Reflective discussions and documentation for teachers are more widely used.
- In many ways teachers follow a similar learning process as their students.
- Learning doesn't always require pen and paper.
- Where possible, there is transfer and incorporation of scientific understandings and skills from one term's Multi Domain unit to the next.

NOW ...

My teaching partner and I moved to teaching Year 3 this year and our VELS Level 3 teachers and students have been involved in some really exciting, rich scientific learning with strong community links. It has been so rewarding for me to see just how far my journey in scientific literacy within a Multi Domain, inquiry based approach has come. Here's a little of what has happened so far this year.

Term 1 Rich Concept: Relationships

We wanted to move the students' learning in Term 1 beyond exploring personal relationships in the unit, 'Relationships'. Together with some scientific insights from our critical friend and Head of Teaching and Learning, as well as our sense that our students are very interested in animals, our Multi Domain unit focused on relationships within the Animal Kingdom, including their interdependence on each other, and their relationship with the environment and with humans. Our focus questions for the students to ponder were:

– What are relationships and why are they necessary?
– What impact do these relationships have on the survival of the animal?
– What part can you play in enhancing and protecting animal relationships?

Immersion activities focused on five different animal species and using different learning mediums the students began to explore and think about scientific concepts such as animal habits, interdependence, survival of the fittest, environmental conditions, the positive and negative effects of humans and predators.

We had an early excursion to the Melbourne Zoo and literacy sessions were full of a wide range of reading and writing tasks to answer students' wonderings and to deepen their knowledge. In Multi Domain activities the students chose an animal to research and an informative presentation in their own chosen format was the assessment task. We had a considerable number of students who became intensely interested in the Zoo campaign to aid the survival of the orang-utan through stopping the use of palm oil – obtained from the oil palm tree, the production of which is severely threatening the habitat of the orang-utan. These students became involved in activities such as collecting old mobile phones for recycling, making billboards and posters and educating other students in the year level, who in turn educated their families on the products that contained palm oil and consequently encouraged them not to buy those products! To me, this is a great example of teachers creating an appropriate learning environment that engaged and empowered the students to learn more about the science in animal relationships, to make connections and take action in real life situations.

Term 2 Rich Concept: Environmental Sustainability

In our first Multi Domain planning meeting for the concept of Environmental Sustainability the teachers identified some obvious links to term one work. That gave me an idea, so I organised that Level 3 teachers and students to visit Healesville Sanctuary (native fauna and flora park). Student discussion, immersion activities and last term's

work had informed us that there was a high interest in endangered animals so we highlighted this aspect to Healesville staff and our focus questions also reflected this direction. We asked the students to prioritise their animal interests and what they wanted to see, do and learn about at Healesville and they were divided into their excursion groups using these criteria. This was a learning strategy we thought would help the students to be responsible and engaged on the day.

Through their various learning experiences in this unit, students were developing and using scientific skills such as hypothesising, "I think the Tasmanian Devil's enclosure will look like ..." and recording and sorting through visual and written observations and information, to find answers to their questions. Scientific concepts such as the optimum environment for the survival of an animal, human impact on an animal's environment and the responsibility of humans to aid the survival of an animal were being explored.

The Healesville staff suggested to me that because of our term focus, we might like to be a part of one of their Community Action Plans aimed at increasing awareness of the plight of some Australian animals. We jumped at this rich learning opportunity and before long, Level 3 students had created and promoted an action plan throughout the school that encouraged students to collect specific plastics that could be recycled. This action would directly help the survival of the endangered Mountain Pygmy Possum whose food sources and habitat were under threat from the effects of manufacturing and climate change.

In fact, just ask our bus drivers, who had to load about 50 bags of plastics on to the buses, if we were providing valuable and rich learning experiences where the students were involved in the decision making, engaged in interactive learning, able to build on prior knowledge and make connections with what was happening in the real world outside the classroom.

Shortly after our excursion to Healesville, an Education officer contacted me to compliment the students on their questions and informed comments and invited us to send some highly able students to participate in a challenging and thought provoking Challenge Day discussing the viability of releasing some captive bred Tasmanian Devils back into the wild. This was the best feedback that I could have received that scientific literacy as part of our Multi Domain units was making a difference to the students' thinking, questioning and application of new knowledge.

The school received a CEO Science Grant which provided funds for fifteen students to travel to Healesville for the Challenge Day and the rest of the grant money enabled the school to purchase a garden bench seat that the company REPLAS produces from the plastics that the community collect and send to Healesville. We now have evidence sitting in our school of the valuable impact that our students' proactive scientific learning has had on environmental sustainability!

Following the Challenge Day at Healesville Sanctuary, the students who had attended were encouraged and empowered to communicate back to the school community their deepening understandings of the complexities of ecosystems, food webs, predators and captive breeding programs for endangered species. I was the facilitator of this learning challenge and confidently felt as though I could step back and let the students take control; allowing the students individually or in groups to

reflect on their second Healesville Sanctuary visit, to research further their particular interest from the experience and to have discussions about what they were finding out. I offered suggestions as to different forms of presenting their knowledge, depending on their preferred learning style.

Throughout this learning process I could see that these students were making connections between their research findings and what they had seen and heard at Healesville Sanctuary.

This scientific learning was giving them practice in observing, data collection and analysing appropriate information, making choices, presentation of knowledge, forming opinions and articulating their findings. Surely these scientific skills will be valuable across all areas of the learning spectrum and will be applicable always in this information laden world of our students. But it wasn't just the students who were benefitting – this was also very rich and valuable learning process for the teacher.

Evolving Learning through Sharing Teaching and a Team Environment

My learning journey in scientific literacy continues to evolve within a team environment that is well supported by the school management and our science experts. Even though I have not participated in the formal STaL professional development program, I am more confident now in the direction that contemporary methodology is taking me. In many ways this confidence has come from working with such an enthusiastic co-teaching partner who embraces change and new ideas comfortably and with excitement.

With an attitude of openness to change in teaching, my partner has led by example, sourcing community experts from anywhere and everywhere, who have made science come alive by helping the students to see the connections between their classroom learning and real life. Why wouldn't children be stimulated, want to know more and talk, write and draw when there is a solar powered car in the school ground, when a big new water tank arrives at school, when shopping trolleys are filled with bottles of water for students' new plants in the adjacent park, when there is an opportunity to build a new invention with dad, when they can go to the windows and watch a hail storm and then make hail stones in the school freezer? Why wouldn't I as a teacher want to be a part of a learning environment and a group of teachers that encourage students to learn in such a relevant, interactive and meaningful way?

An integral part of this growing confidence in myself and the teachers at school, (both oldies and newies) to have a go at helping our students to be science literate, is the ongoing, in-house professional development and support that we have twice a term with our Head of Teaching and Learning and our critical friend.

It's relatively easy for teachers to bounce ideas around, make phone calls to community groups, and plan busy activities, but it is much more challenging to understand the science concepts, connections and thinking that we are aiming to develop through our Multi-Domain units. Our science leaders help us to do this - and we are becoming more confident in our abilities to do this, too.

A FINAL WORD ABOUT UN-BOXING

Through my experiences at OLGC, I have un-boxed my science teaching practices, and at the same time I am attempting to define the meaning of scientific literacy. From my experiences so far I am wondering if scientific literacy is the integration of scientific principles, knowledge, language and processes into an inquiry based curriculum which allows students to learn that science is all around them, not just in the laboratory and in teachers' boxes? It is a deliberate attempt to place science teaching and learning into a meaningful and relevant context for each student so that a deeper understanding of the world is gained through exploring, questioning, finding answers and applying these to other situations.

Just like my students who are being prepared to be lifelong learners, I too will continue my journey of refining and redefining my thinking, learning and teaching practice of scientific literacy. Un-boxing never stops.

Rosemary Cussen is a Grade 3 teacher at OLGC.

PERNILLA NILSSON

14. WHY DOES SCIENTIFIC LITERACY MATTER IN PRIMARY SCHOOLS?

Reflections on the OLGC Experience

When I was invited to Melbourne to spend a week at Our Lady of Good Counsel (OLGC) primary school to observe what they were doing about scientific literacy in their teaching, I could not have anticipated then what I would come to see and understand. I was asked to come to OLGC from Sweden to offer an external perspective based on my experience as a Primary Science Teacher Educator. The teachers made me feel very welcome and it soon became obvious that their participation in the STaL project (Science Teaching and Learning) over many years had been an important shared experience that facilitated their thinking about scientific literacy.

STaL specifically sought to develop teachers' knowledge of science teaching and learning, and through different activities helped participants to better value their knowledge, skills and abilities as teachers. As a consequence, when OLGC became involved in the Scientific Literacy Project, their use of a critical friend was important. The main role of the 'critical friend' was not to increase teachers' content knowledge but to help them see scientific literacy as an approach to everyday teaching.

In introducing this chapter about what I saw, and how I interpreted my experiences in the school, I will start by revealing my conclusion. The OLGC primary school is a school that wants to keep getting better at what they do all the time. Standing still is not good enough, they constantly look for development. From my experience, that is rare, but it is also a main prerequisite for sustainable change in professional practice. Having revealed my conclusion, I will now go back and reflect on what scientific literacy is at OLGC and then respond to the question of why I was impressed by what I saw during an exciting week being involved in teaching and learning of scientific literacy in a primary school.

SCIENTIFIC LITERACY IN PRIMARY SCHOOLS

Over the last ten years I have been working with primary pre-service and in-service teachers to explore how the use of exciting teaching methods such as squeezing balls from air canons, amusement park and playground physics and practical experiments can stimulate science teaching and learning and positively influence students' attitudes and interests. Through that work I became involved in developing a Science Learning Centre at Halmstad University in which children aged between four and eleven could visit to work on experiments and develop their problem solving skills in science.

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 127–137.

In the Science Learning Centre pre-service science teachers were offered opportunities to practice science teaching with these young students and the students got a little "taste" of the exciting world of science. Through the laughter and shouts of excitement the pre-service teachers and the young students build boats and cars, they launch carbon dioxide rockets made with baking powder and water. They have also built twinkling Christmas trees and vacuum cleaners with water bottles and small engines. The big challenge for the student teachers working in the Science Learning Centre is to transform their subject matter knowledge in a way that was makes science learning more accessible for their students.

During my time running the Centre, I have noticed how teachers' attitudes, self-confidence and science Pedagogical Content Knowledge (Nilsson, 2008; Shulman, 1986) stands out as critical to how their students experience science teaching. My view is that as science is all around us, teachers need to develop the skills to catch their students' ideas, stimulate their questioning and develop their scientific reasoning. When a child is balancing in a tree or riding in a swing, it is science. When a child places snow on a slippery dip (slide) to minimize friction, it is science. When driving in bumper cars at the amusement park and they crash into each other and their bodies continue to move forward, they are experiencing Newton's first law.

Young students have a natural inclination for, and creativity in, science; they are curious about the world around them. For a primary teacher then, it is important to stimulate their interests and challenge their ideas and encourage their questions.

My experience in working with primary teachers is that they are often challenged with, and confronted by, obstacles in teaching science. Often, instead of creating opportunities and guiding their students through the exciting world that science offers, they feel inhibited. The science education research literature consistently draws attention to the perceived lack of knowledge and skills in primary teachers' science which contributes to their low confidence levels. This problem appears to be a common concern all over the world. For example, Harlen (1997) found that primary teachers in England ranked science as 8th on a list of 11 subjects in term of confidence in their ability to teach those subjects. Early in my career as a primary teacher educator, I saw the importance for teachers to reflect and learn about how new science teaching and learning practices need to be developed in their existing classroom practices.

Given the complexity of these issues, it might well be asserted that in order to plan learning experiences that engage and challenge students' thinking of science, teachers need to develop better knowledge of science teaching and students' learning in ways that allow such knowledge to be adequately translated into meaningful practice. One way of so doing is to use an approach to scientific literacy to foster active learners who engage in thinking and working scientifically. As such, scientific literacy then focuses on the needs of students as future citizens who will engage with science at a personal and a societal level. This therefore means more emphasis needs to be given to science as a way of thinking and working in the world.

Rennie (2005), in her unpacking of the characteristics of a scientifically literate person, emphasised an action-orientation (see Figure 14.1).

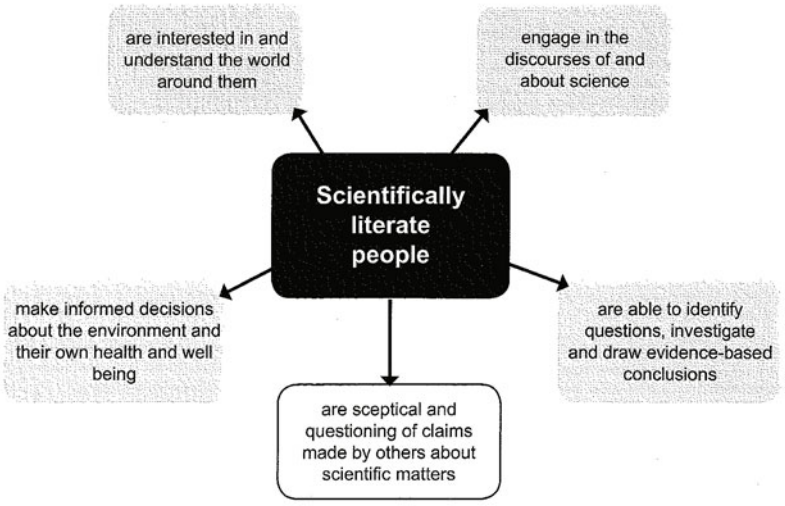


Figure 14.1. Rennie's (2005) definition of scientifically literate people.

As Rennie suggests, scientifically literate people are: interested in and understand the world around them; engaged in the discourses of and about science; able to identify questions, collect data, and draw evidence-based conclusions; sceptical and questioning of claims made by others about scientific matters; and, able to make informed decisions about the environment and their own health and well-being. Such a definition requires that people have certain skills and abilities that enable them to cope in life both within and beyond the classroom.

Coming from Sweden to spend a week at the OLGC to observe and discuss approaches to scientific literacy with this thoughtful group of primary teachers most certainly gave me new insights into how to successfully implement scientific literacy in primary school classrooms.

WHAT DID I SEE AT THE OLGC?

Teaching Science through the Lens of Scientific Literacy

During my years of working in Swedish in-service and pre-service science teacher education I have seen a lot of primary science teaching. When I left Sweden for OLGC, I had high expectations about what I might experience, but, at the same time I was also nervous about getting access to teachers' planning sessions and teaching activities. I was asked by my colleagues at Monash University to observe the primary teachers, to talk with them about what, how and why they were doing scientific literacy, and to see how their work with scientific literacy influenced their actual classroom practice.

During the week at the OLGC, the teachers invited me into everything as I participated in different planning meetings with all groups (Year levels 1–2; 3–4 and 5–6)

and was freely invited into classrooms to get an idea of how their planning was implemented in their classroom practices.

The planning sessions gave me a good picture of how the teachers selected their content for teaching, why they chose their different teaching methods and how their teaching related to scientific literacy. I also conducted deep interviews with all participating teachers and their critical friend.

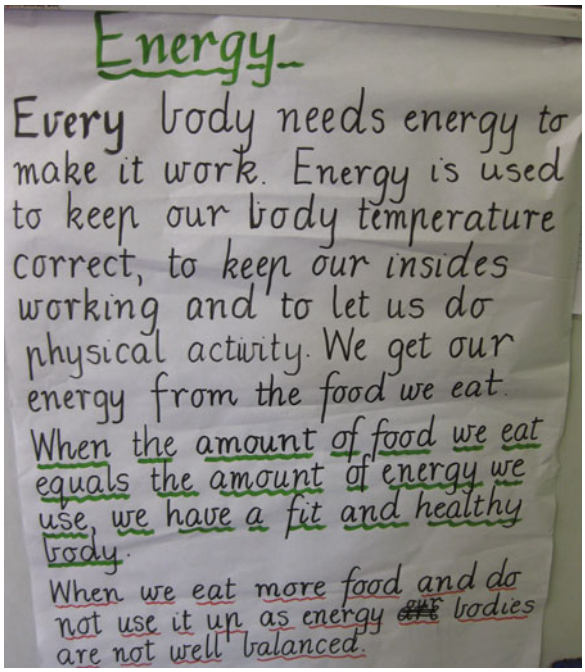
During a period of two years all teachers at OLGC were involved in conducting eight different multi-domain units. These units were Identity, Change, Communication, Wellbeing, Relationships, Ecological Sustainability, Technological Advances and Safety. As such the different units were taught in all levels at the same time and the teachers worked very hard to let the ideas from one unit continue into the next unit. Considering the topic of Wellbeing, the students in the Prep class dealt with the question "what is well being?" and the students in Year One worked with nutrition and what they needed to eat in order to feel well. In that way, the unit of Wellbeing was built-up in ways that were deeper and/or broader for every year level. All teachers at the school were involved in this integrated way of working. It really is a whole school approach.

Teachers consistently told me that before they had participated in the scientific literacy project that they used to teach science in a different and less coherent way. Before joining the scientific literacy project they said they would've spent about three weeks teaching science, three weeks teaching Civics, and so on. They also mentioned that at that time, they might even say that they would not teach, for example, geography because it was not part of the work for that week. One of the teachers mentioned that it got to a stage where some people said that they would not do science because it was not *their* science unit.

Over the last few years OLGC has looked at how to deliver the curriculum in another way. Instead of being narrow and sticking strictly to the different subject content units they have opened up a much broader conversation around what constitutes a unit. Working with scientific literacy as an integral component of all content areas has led to an important shift. As I see it, the OLGC teachers appear to value a broader approach to teaching and learning than the traditional specific boxes. For example, in the unit on Communication, the Year 3–4 students developed an advertisement for the school. They asked a lot of questions of teachers, parents and staff at school. They tried to get ideas about target groups to whom they should advertise, they developed graphs, brought in information, analyzed and categorized and then tried to develop generalized topics about how to advertise school.

What also became very clear to me during these sessions was that the teachers always seemed to select and apply science content relevant to the students' daily life. As they are exposed to scientific concepts everyday through the media, the teachers want the students to question their world, to think about the world around them and how that impacts them. Further to this, there is a clear teacher focus on students seeking information to explain new phenomena, to solve problems and to feel comfortable to listen to, to read, write and talk about science in everyday situations. The approach is inquiry based. They teach students to go out and get information, to ask questions, to be curious and engaged. They use journal articles about things

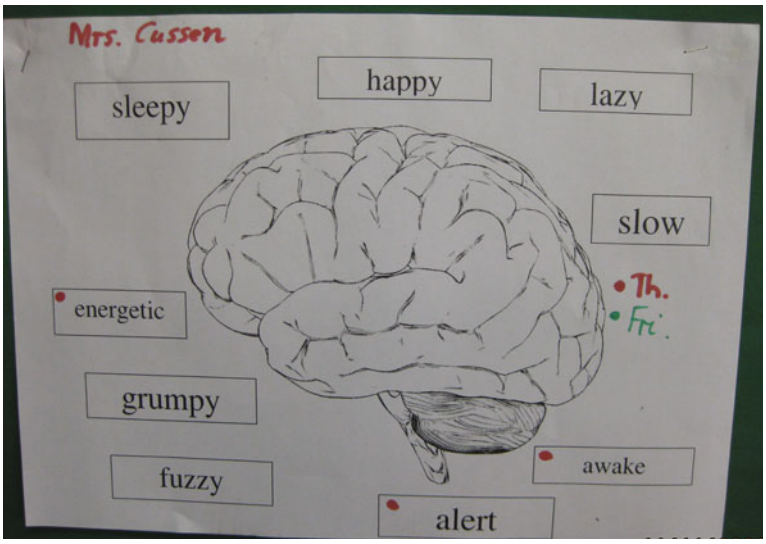
connected to science. I heard them talk in a commonplace type of way about DNA and how mutations occur in animals and plants. There is an over effort to include some scientific connections in literacy; for example energy, forces, genetics, etc. In Year One in particular they worked with energy as illustrated in the reading below.



What is immediately obvious is that by working with the notion of scientific literacy teachers incorporated science into all subject areas. One indicative example was during the unit sustainability in which they read newspaper articles, journals, text books, etc. in order to work with language and discuss different writing genres. In religion they discussed sustainability and how to make a sustainable world for families to live in the future.

Other examples I became familiar with included the unit on Identity where students developed an awareness of their own identity and the diversity within their world. In the unit on Change although there was work on climate change there was also personal and identity change and how animals, humans, and landscapes change as well as changes in technology.

In order to combine the unit Wellbeing with literacy they worked with scientific texts. As science texts are often quite difficult they made their own informative texts together with the students. During these activities they gave the students different science words (such as energy, brain etc.) and then together they used the words in discussions, drawings and stories. All their reading is in one way or another connected to the unit of Wellbeing and is designed to improve their communication and language; they also developed a role-play on healthy lives.



Interestingly, they also connected Wellbeing to activity and then used that link to explore what happens in/with the brain when considering the physiological differences between being active or passive.

One of the teachers described how she worked with the brain for several weeks using different activities:

> *We decided that we wanted to investigate their healthy life across a whole week from Monday to Sunday. We investigated how they felt, their eating habits and actually looked to see if they had eaten enough of that specific food group, and in last week we were talking about the brain. How does your brain feel? We took them out on activity and they had to say how they felt before and how they felt after and then compare and make a decision about why they felt different. (Alissa)*

BUILDING ON STUDENTS' IDEAS

To start a unit the teachers often begin with "immersion" where they conduct a brainstorming activity and let the children do pictures that describe their thoughts and questions. Through that, and in collaboration with the students, they can identify some goals and the questions that form the basis of what they will explore in the unit. During immersion they pick some aspect from the next unit so that the students get an opportunity to become familiar with the words and concepts that are going to be developed later in the unit. So when it comes to actually teaching the units the students are already in one way familiar with the vocabulary and have that preknowledge. For example, in the unit of well being they started with brainstorming in which the children came up with a lot of questions and concepts connected to well being and then sometime into the unit they had opportunities to revise and refine the concepts and explore them further.

Defining the students' ideas of wellbeing on the wall also helped teachers to work the students to come back to the different definitions and revise their initial ideas:

> ... today we think that wellbeing is this, but one week ago did we all think that was what wellbeing was? How has our thinking changed?

This approach is a good way to encourage reflection on what a concept means. Another example I saw was in how students designed questions. That is illustrated in the display below on clouds which was connected to the unit Change.

Another example of building on students' ideas was the "Question Wall" where all the students and the teacher put up their different questions.

I listened attentively as Stephen stressed to me that the reason why he put his own questions on the wall was that he wanted his:

> *... students to understand that as a teacher I also have inquiries and that I do not always know all the important facts or bits of information.*

Several teachers mentioned that students really have scientific minds, they hypothesize all the time, have a natural sense of curiosity and wonder a lot about what happens around them.

Another aspect of how students build on each others' ideas was in the Prep class. There is an explicit way of building on ideas, not repeating them:

> *usually when one student says red, the next one says red and then the next one says red too. Now they have a different way of building on each other's ideas and if someone now repeats what another already has said, there are at least five children that shout out "we have already said that, come up with new ideas!"*

SCIENTIFIC LITERACY MATTERS FOR TEACHERS' THINKING

My experiences of working with primary teachers is generally that they tend to lack self-confidence in teaching science and that, as a consequence, science lessons are often mainly teacher directed. What struck me at the OLGC was that teachers

seemed to be confident in their roles in the classroom and worked in an inquiry based manner in which they stepped back and let the students be active participants in all aspects of learning. For example, Mary spoke to me about how she had learnt that it is not always the right answer that is the important thing but that it is to help students to see the purpose in why they learn things and the way they can use that knowledge in their everyday lives. Hence, the ideas that was continually reinforced for me was that these teachers were not driven by the need to always have the right answer. They demonstrated time and time again that they relied on a process in which they supported students in being responsible for their own learning.

At OLGC, they challenge students to question their world and try to help them see that science is not always about experiments and people in white lab coats; science is all a part of our everyday world. Ann offered an example of how she had initially struggled with the process of letting her students build on their ideas, because she knew that they were not always scientifically correct, but she had learnt to take a step back and not feel the need to always come up with a right answer. In so doing, she explained how an inquiry process made a difference for their learning:

> *One of the students said that frogs lay eggs too and I wrote it down and they continued to say that the mother frog sits on the eggs and I said oh ok … and I wrote it down such as if it was true and some of them were quite sceptical and when we looked at it in the end of the year they said that we did not say that and I said yes you did and they couldn't believe that they used to think that. Yes, that was very powerful to show them how their knowledge developed. I felt very unsure of it and the idea of writing down things that you know are not true is quite frustrating as you are so used to modelling the reality. You want to be in control and it feels a bit strange to let them go but this is an inquiry process.*

I was impressed by the way the teachers highlighted that there had been a shift from their own thinking about where to find science in a unit to now seeing that science is everywhere. The teachers told me that they had revised their way of thinking about science and scientific literacy and that now, scientific literacy means discussion, argument, communication, investigation and questioning the everyday world. They have changed their way of thinking of trying to have correct answers for all students' questions to take a step back in the classroom and not tell the students the right answer all the time. They feel more self-confident in that they can work with science in the classroom and discover together with the students rather than simply teaching to the students. Before the project they thought (and their students thought) that science was about doing experiments, now they know that it is so much more:

> *working with Kathy [critical friend] and doing all these things has been a big learning curve, it's not all about experiments and right answers.*

The fact that they saw how it was that so many previously felt a need to be in control was an eye opener for them. STaL helped them to think in another way, a way that

allowed them to help their students explore their own ways of thinking. They found how they did not have to have all the answers but needed to feel more confident to step back and let students share their ideas. All of the teachers stressed STaL was an awakening. However, beyond STaL they had experienced scientific literacy as something much broader than only science activities; it is in the everyday that counts. Mary captured this quite well:

> *Scientific literacy expands your own way of thinking as a teacher and makes your teaching richer than it used to be. It is very satisfying. All this is a good learning experience even for us and we are working with our own inquiry in the same way as the kids are into their inquiry. STaL was a big eye opener because it made you think. Before STaL, doing an experiment was more like leading the students through it heading towards the correct answer. Scientific literacy is much more about inquiry, asking questions and all that. We have an idea of the skills that a scientist has, the asking how and why questions and so we also try to encourage our students to do the same. Let us find out if we can get an answer. We got inspired by STaL in that you don't have to have [preordained] expectations, rather that you are free to question. You don't need right answers.*

CONCLUSION

In my week at the OLGC I was very impressed by the way the teachers took the ideas of scientific literacy into their everyday teaching. As Rennie (2005) highlighted, scientifically literate people are interested in and understand the world around them. Just as Mary stated (above), as teachers they are working with their own inquiries in the same way as their students are working with their own inquiry. In order to understand the world of science teaching and learning, teachers need to be inquirers into their own teaching and their students' learning in ways that also make them question, collect data and draw evidence based conclusions about their science teaching and learning processes.

To be a scientifically literate teacher requires having certain skills and abilities that enable one to cope with the teaching of science in a changing world.

> *Science does not take a part of the day … it sort of permeates everything that we do. It does not come a long only as a science lesson. (Mary)*

This I believe is the approach that makes for a scientifically literate teacher; I met and saw in action many such teachers at OLGC.

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Associate Professor Pernilla Nilsson is a Science Teacher Educator at Halmstad University, Sweden.

JOHN LOUGHRAN

15. RESPONDING TO THE CHALLENGE OF SCIENTIFIC LITERACY

A Whole School Approach to Scientific Literacy

Having been involved in the Science Teaching and Learning (STaL) program for the last few years, I could not help but be continually drawn to Our Lady of Good Counsel (OLGC) Primary School to see what they were doing as a follow up to their STaL experiences. Each year, a number of OLGC staff would enrol in STaL and each year, their sense of involvement and commitment to their own learning was clear for all to see. It did not take too long to realize that the school had made a serious commitment to science teaching and learning.

When opportunities arose to visit OLGC I was always keen to drop in and see what was happening. The teachers were happy to talk about what they were doing in their classrooms and how they had used STaL as a springboard for their own professional learning. Visiting OLGC was enjoyable because staff were always enthusiastic about what they were doing and more than ready to share their experiences about how their students' learning in science was developing in new and exciting ways. In addition, the school's leadership took pride in the way the staff were engaging with science and actively supported their work. As a consequence, I always had a sense that science teaching at OLGC was being positively challenged. The changing nature of students' learning seemed to continually reinforce for all involved the value of pushing the boundaries in their own practice.

Over time it became obvious that OLGC was a school in which change was being driven by teachers' concerns and issues about science curriculum, teaching and learning. As a consequence, the school as a whole constantly rose to the challenges of teaching science for understanding in ways that are not possible when change is mandated by others or directed solely from above.

With the support of the Catholic Education Office Melbourne (CEOM), OLGC grabbed the opportunity to pursue their concerns about science teaching and learning in an organised and systematic way. The school became involved in a project titled Valuing & Promoting Scientific Literacy in Science Teaching & Learning and set out to explore and clarify scientific literacy in terms of the practical implications for both curriculum and learning by implementing a multi-domain inquiry planning approach. Through this multi-domain approach, teachers were not only encouraged to consider some of the key ideas around scientific literacy but to also engage in professional discussion and examine alternative approaches to planning and teaching in an attempt to provide effective conditions to enhance scientific literacy for all students.

J. Loughran et al. (eds.), Scientific Literacy Under the Microscope: A Whole School Approach to Science Teaching and Learning, 139–148.

The school began to trial an all school multi-domain inquiry approach to curriculum planning designed to foster meaningful links across curriculum areas in order to enhance students' learning across subject areas. In collaboration with the CEOM, the school was able to employ a critical friend to support their school based professional learning project.

The idea of a 'critical friend' was based around providing specific planning support for teachers across all levels within the school. Specifically, the role was about building the decision making capacity of teachers and focusing their conversations on the development of key thinking and communication skills and science concepts that might support students in developing their scientific literacy. The approach was based on thinking about topics in different ways and from different teaching and learning perspectives rather than viewing teaching solely from a particular content area.

In collaboration with the Teaching and Learning Coordinator, over an extended period of time, the critical friend supported classroom teachers. Through that support teachers became more expert at articulating their pedagogical reasoning as they responded to changes in their students' learning.

With all that I could see that was happening at the school, I tentatively sought their permission to become an observer of the process and to bring a research perspective to their work in order to capture the essence of their journey of development and change. The staff responded positively to the request even though, initially, it did not appear to them as though they were doing anything special.

> *... [when he came to ask about researching what we were doing] he was saying that it's quite unique what is happening here ... [after he left] we sort of said ... we're not doing anything special. We don't consider anything we are doing as special and I suppose it is because when you are in ... when you're doing it [you don't see it]. We know that having Kathy Smith [critical friend] as part of the team we certainly have science on the agenda for every single unit, every single term science is there. Whereas in the past, we hadn't – it was just every now and then it was sort of mapped out that we would do a science topic. But now it is linked through to everything ... so that is a big change. Apart from that we ... we were always saying ... oh, was that a good enough session ... and was the unit, you know, good enough ... and so I think we are doubting ourselves. (Teacher interview, 24/06/09)*

This book is one obvious outcome that has resulted from a process of teacher led educational change. However, that is not really where the story begins. It is actually embedded in an ongoing argument in the research literature about scientific literacy. An argument that, at the time, I personally thought had little real meaning in the daily work of teachers. To me, the academic debate surrounding scientific literacy seemed separate and removed from the busy world of teaching. How wrong I turned out to be.

THE SCIENTIFIC LITERACY DEBATE

> Scientific literacy has become an internationally well-recognized educational slogan, buzzword, catchphrase, and contemporary educational goal … The

> term is usually regarded as being synonymous with "public understanding of science" ... (Laugksch, 2000, p. 71)

The debate about scientific literacy typically draws on arguments that have existed for a considerable period of time in science education around curriculum design, meaningful learning, student engagement and relevance of science learning in school classrooms. Roberts (2007) captured the essence of the debate when he drew attention to two differing positions (Vision I and Vision II) of curriculum design. Vision I he described as scientist-centered with a strong focus on science content knowledge. On the other hand, he described Vision II as being more student-centred and context-driven. When reviewing Roberts' ideas, Aikenhead (2007) pointed out that Vision II "seeks to enhance students' capacities to function as life-long, responsible, savvy participants in their everyday lives; lives increasingly influenced by science and technology" (p. 1).

It is not difficult therefore to see how a Vision II view of the curriculum would be appealing to teachers as it moves well beyond ideas about the transmission of science as facts and knowledge. However, not so easy to see are the implications inherent in implementing such a vision in science teaching. Chasing the vision brings into question not only what is taught, but also how it is taught - and that is when academic debate really can impact the work of teachers.

Fensham (2008) argued that, "scientific literacy does not have a fixed meaning or definition. Nor is it a single notion" (p. 28). If there is no fixed meaning, then how do teachers define scientific literacy and what does it mean for how they plan for and conduct their teaching?

A CHANGING VIEW OF SCIENTIFIC LITERACY

When OLGC embarked on their scientific literacy journey, I was of the view that the value of the term was mostly about encouraging teachers to be more focused on their teaching of science. For the most part, I felt as though scientific literacy itself was first and foremost about good science teaching and learning. Any philosophical basis for teachers' developing scientific literacy in primary classrooms – I assumed – would be of little interest or concern to them. That view was based on my belief that teachers were generally more interested in finding 'activities that work' (Appleton, 2002) rather than questioning deeply the what, why and how of their science teaching per se. And, that view was based on my experiences in STaL in which we had worked with very committed and capable teachers who showed deep concerns about developing more engagement in science learning in their classrooms.

STaL teachers' efforts to better engage their students in science were continually highlighted to me through the final day of the STaL project - which is a case writing day. Cases are one way of encouraging teachers to articulate and share their professional knowledge of practice (Lundeberg, 1999; Shulman, 1992). Interestingly, across the cases that have been published over the past five years (see, Berry & Keast, 2009, 2010; Loughran & Berry, 2006, 2007, 2008), the majority are about implementing a new teaching procedure in the classroom. Hence, the major focus for many STaL participants (when they were asked to write about what they had

learnt) was defined by an activity that worked. That is not meant as a criticism, rather it is the reality of the need to interest and motivate students in learning science and to do so in a regular and ongoing way. To do so is demanding in ways that those not experienced in teaching would no doubt struggle to fully understand. The constant pressure to do something that will engage students in learning is not easy in the rush bustle of school life.

Any reading of the STaL cases illustrates that they are thoughtful, reflective insights into developing teaching and highlight the importance for teachers of being able to develop and refine an array of teaching procedures and activities that will engage their learners in learning about science. For example, consider the following conclusion from one case in particular:

> After attending the STaL program I discovered many great activities to get discussion going in the classroom about science topics. Most, I thought, were more appropriate for the older kids. But this activity [hoops and cards described in the full case] had generated some genuine discussion amongst my kids. They had justified answers, they had created their own guidelines, they had considered their responses and they did not want to let this activity go. We used the hoops and cards for three days. The children then created their own Venn Diagrams on paper. The beauty of this activity was in seeing how they justified their decisions.
>
> From the teacher point of view I had taken a step back and allowed the students to mostly take control of the lesson. This was a big step for the control freak within me. It was also a challenge for many of the kids who are so accustomed to instant responses from the teacher about their thinking.
>
> The students rose to the challenge and surprised me with the way they responded to each other and to the lesson. This was one of those lessons that brought results beyond what was expected and produced a couple of great 'wow' moments. Now for the difficult part – how do I recreate the enthusiasm and the environment for this to occur again? (Fraraccio, 2008, pp. 48–49)

Activities that work is not meant to convey a pejorative or demeaning view of teachers. Rather it is an acknowledgment of the real demands of teaching on a daily basis. The reality is that teachers constantly need something for their students to do that will bring the content to life - and that can be very difficult to do if science as a subject is created in the image of Roberts' Vision I. Hence, teachers' focus on activities that work is a very important beginning point for creating a real sense of interest in science; but of itself, is not sufficient when considering issues around conceptual learning in science. Again, that is where the OLGC teachers illustrated approaches to, and thinking about, pedagogy that made me look again at what they were doing.

Having observed, interviewed, discussed and collaborated with the teachers at OLGC over the last few years, I can honestly say that my views about what scientific literacy means, looks like and does in their classrooms has changed. By exploring how the OLGC teachers thought about scientific literacy as they embarked on and

conducted their project, it became increasingly clear that a substantial shift in their views and practices took place such that:

> ... it is clear through the questionnaire data that [OLGC] teachers were able (at end of year 2) to articulate their thinking about scientific literacy and consider what scientific literacy might look like in the classroom. … there had been a shift in [their] understanding [of] the nature of the concept in such a way as to suggest that scientific literacy was no longer viewed as an 'extra' or an 'add-on' specifically linked to classroom science teaching and learning. The questionnaire responses indicate that many teachers not only moved in their thinking about the nature of scientific literacy but also that they came to express their understandings of scientific literacy in ways that conveyed a complex interconnecting idea of teaching, learning and living. … Those teachers who expressed a more complex understanding made comments in the questionnaire which suggested that they expected to see students approach learning in rigorous and intellectually demanding ways including: taking apart issues; analyzing; sorting; reconstructing; defining; explaining; redefining ideas; sharing information; learning from each other; trying to understand or make a difference to the world in which they live; categorizing; using deeper thinking strategies; and, making connections. Where teachers listed such indicators as expectations for their students' learning, they also indicated a higher level of impact of scientific literacy on student thinking. It may well be reasonable to suggest that these teachers' behaviour actively nurtured and valued this view of scientific literacy through their practice. (Smith, Loughran, Berry & Dimitrakopoulos, 2010, p. 17)

A CLASSROOM VIEW OF SCIENTIFIC LITERACY

As the previous section makes clear, that which I thought and then came to know by working with the OLGC teachers challenged my preconceived ideas about what might be possible through a focus on scientific literacy. These teachers approached their professional learning and knowledge development in ways that superseded more routine teacher responses to the daily demands of classroom teaching. They were actively building knowledge of teaching for scientific literacy in ways that were not designed to simply entertain students or encourage them to have fun in science, they were actually working to develop students' scientific literacy across all aspects of their learning. Engagement in learning science at OLGC was about deeper conceptual understandings that emerged through thoughtful approaches to pedagogy that were critiqued and reviewed in a professional way as part of the school's approach to enhancing the curriculum and professionally developing staff in meaningful ways. Tracy Adams offered insights into how that was happening through the case she wrote on the StaL writing day. The extract below captures the essence of the ways in which she was beginning to respond to that challenge:

> **Changing the teaching script**
>
> I suppose I was in a comfort zone for delivery of science curriculum. I'd research concepts, understandings and topics. Then I'd organise tasks that would reflect what I thought was important to learn.

> But was it?
>
> Ideas presented at the Science Teaching and Learning [STaL] days provided me with the opportunity to step back and reflect on my classroom practice.
>
> Questions that came to mind were:
>
> "What can I do to allow the students more input into their learning?"
>
> "How do I guide possible directions for students' learning whilst still allowing them room to explore?"
>
> It just so happened we were actually developing a unit of work on CHANGE and the relationship that exists between cause and effect in this process of change.
>
> I wanted the students to develop their own understanding and definition of Change and it was my first step in changing my approach. I was not going to tell my students what I thought the definition was.
>
> Giving the students time to use their own language and refine definitions was next. I began to hear:
>
> "I like that definition. It's the same as mine."
>
> "I agree with you, but what if we …"
>
> "Perhaps it could be a combination of …"
>
> I still hadn't intervened with any input at this stage.
>
> My students were enthusiastic and comfortable to share their understandings and ideas and be part of a really animated conversation. I didn't do too much 'teacher talk'. Throwing in a, "Have you considered …?" or, "What if …?" was all I did.
>
> **A different role**
>
> My responsibility was to provide resources, opportunities and experiences that allowed my class to sort through new information and information already known. This would give my students a grounding from which to continue developing their own area of interest within the topic.
>
> And that's exactly what happened! (Adams, 2008, p. 16)

Tracy's (full) case illustrates how her approach to practice involves so much more than developing an activity that works in her classroom. Her writing shows that she was actively pursuing ways of reconsidering her approach to teaching science in such a way as to create a different teaching and learning environment – both for herself and her students. From my perspective as an interested observer of the work being done at OLGC, I was certainly of the view that Tracy's approach to thinking about teaching was indicative of that which was becoming the status quo at the school – and has become that now at the time of writing this book.

Perhaps the shift in thinking and approach to teaching I am alluding to – that is quite subtle in some ways and also very important in others – in terms of moving from activities that work to an integrated understanding of science in all things, not just the prescribed science curriculum, is best demonstrated through the following extract.

> *Interviewer: I think that sooner or later you still need good activities, and then how they get tied together becomes really one of the issues, but you walk into the class and you still need to have something to do.*
>
> *Teacher: You do. But I think we'll never, ever get past the fact that kids think science is experiments and kids love experiments. I know in the year 3–4s they are doing change and they are doing lots of experiments. We, in our level, borrowed the box [from university science centre], which is full of experiments, but after our planning [multi-domain planning session] we had to order it early, but after our planning (we are doing the weather) I don't know that we are actually going to use the box – it doesn't actually fit anymore with how we work ... because that [old] way of planning has gone.*
>
> *[For example] come Science Week, why [is it] Science Week? we are doing science all the time it shouldn't be - why are we having Science Week, because every day should be science day for us. So I guess the tricky part for me is, and it will probably be my task to look for, something for Science Week. We will have Science Week, but I guess we will be celebrating the science that we do all though the year in Science Week. We'll have to bring it in that way. It can't be a show. But we will be up to technology [in multi-domain planning approach to topics], so we will be looking for some elements of technology for science that will fit with wherever every group is at, it will need to enhance what each group is doing. It won't be something out of the blue. So Science technology, we'll see where people are at by that time, but that's what we will be going for. (Teacher interview 29/05/09)*

What this interview extract illustrates is that science is not an 'add on' to the existing curriculum. The idea that science is part of everything that is done and is a normal way of thinking about everyday events in the world is an integral part of the approach to developing scientific literacy rather than making it something special or different or difficult in terms of classroom teaching and learning. Traditionally, Science Week is a challenging and demanding time for primary schools. They typically work hard to develop examples of 'sciencey things' to display. This interview extract shows a major change in thinking and practice that challenges that 'one off display' approach that implicitly detracts from science as a way of understanding and explaining the natural world. For me, thinking about Science Week the way that it is explained (above) captures the essence of what the OLGC teachers have been doing. Their understanding and approach to scientific literacy has changed and has, paradoxically, become more simple yet also more sophisticated; it has become a part of what they do, not something they need to remember to refer to or remind their students about.

Having interviewed the OLGC teachers about their efforts to develop scientific literacy with their students, and certainly as a consequence of working with them in writing their chapters for this book, I have no doubt that they have developed an understanding of teaching and learning in science that is both impressive and distinctive. The thinking that underpins that approach is illustrated in the following quote:

> *Well we still wonder, all of us wonder, whether we are on the right track with scientific literacy but what I see it as, is it's now a way of thinking really. That you want the children to become just more questioning about their world and about what each other are saying and even about what the teacher is saying. We want them to know, to sort of question what is going on [to ask] is that really what happens? and, how does that work? Then within your classroom I think scientific literacy, from my point of view, is that they need to be controlling discussions a lot more. (Teacher interview 24/06/09)*

The ways in which these teachers reflect upon, consider and construct their teaching for scientific literacy clearly stands out as crucial to shaping the manner in which they conceptualize and conduct their practice. The change is not as simple as explicitly aligning with Roberts Vision I or Vision II. Rather, it is embedded in the type of thinking that underpins the difference between science largely as facts and information and science as an invitation to make sense of everyday phenomena, through teaching, to develop meaningful ways of exploring those phenomena on a daily basis in the classroom.

CONCLUSION

Much has been written over the years about the difficulties associated with implementing change in schools. Fullan (1993) explained how genuine change is built on four key characteristics: personal vision-building; inquiry; mastery; and, collaboration. All of the chapters in this book illustrate how these characteristics have come together at OLGC to support change in a positive way. However, for me, one of the key features that stands out as making a real difference has been that of collaboration. In many ways, the notion of collaboration is paid lip service in schools because the traditional view of teaching is of the teacher out the front directing everything in a masterful way. However, as the OLGC teachers have made clear through their chapters, the way that they have collaborated in their multi-domain planning approach, their sharing of professional practice, their honest critiques of their own teaching and learning, and their desire to work together to make a difference, has created a new way of thinking about collaboration in teaching.

These teachers' approach to collaboration has challenged the more traditional approach to teaching as an isolated and covert activity (Ginsburg & Clift, 1990). By genuinely sharing together through free, open and honest discussions of practice, by using the multi-domain planning approach as a way of looking into practice with new eyes, these teachers have developed a more professionally rewarding approach to practice.

The team work inherent through the combined support of the CEOM, school leadership, the Teaching and Learning co-ordinator and their critical friend, has enabled these OLGC teachers to take control of their own professional learning in ways not typically realized in schools. Yet, interestingly, despite all the attention that their efforts have attracted, they have not necessarily seen that what they were doing was necessarily anything special.

I think that as a consequence of the way that teaching is conceptualized and educational change is imagined, that the type of educational innovations so often sought after are perhaps too easily overlooked. For me, that is a shame and is largely as a consequence of narrow views of teaching being applied to very complex and sophisticated work.

What these teachers have documented about their professional learning in this book is something that needs to be more widely recognized and prized. They have offered insights into their professional knowledge through their everyday questioning of practice, their desire to continually enhance students' learning, and through an expectation that their professional growth is driven from within – not mandated by others. These teachers have made clear the nature of educational change in ways that have made a difference in their school, and hopefully through this book, might do the same for others.

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Professor John Loughran is the Foundation Chair, Curriculum & Pedagogy and Dean of the Faculty of Education, Monash University.

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