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Science teachers' professional development: An Australian case study

John Loughran
Faculty of Education
Monash University

Correspondence: john.loughran@monash.edu

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Background

Australia is a federation of six states and two territories. Education is primarily the responsibility of the States and Territories and so differences in priorities and/or expectations can lead to variability in policy between States and Territories despite overarching efforts by the Federal government to influence the overall policy agenda. The schooling system in Australia comprises government schools (which approximately 65% of students attend), Catholic schools (approximately 20% of students) and independent schools (approximately 15%). Although policy is set by Government Education bureaucracies, the Catholic and Independent sectors also have the ability to adjust and adapt policies to suit their particular needs.

Over at least the last 20 years there has been a consistent focus across the Australian Education Systems on the nature of teacher professional development. As a consequence, what professional development is, how it is constructed and delivered, and how it is experienced by teachers has consistently attracted attention. Science teaching and learning in particular continues to be in the 'professional development spotlight' not least as a consequence of the result of international measurement programs such as PISA and TIMSS.

Australian outcomes from PISA and TIMSS have meant that all levels of science education (K-12 and university) have come under closer scrutiny. As a result such things as national science testing (ACARA, 2010) and Professional Development funding have been initiated in an attempt to respond to the perceived decline in overall science performance.

Across the States and Territories, as well as at a Federal level, Science and Mathematics school teaching and learning has been examined in detail (ACARA, 2010; DEECD, 2009; Rennie, Goodrum, & Hackling, 2001), resulting in a similar recurring message that the:

> *… actual picture of science teaching and learning is one of great variability but, on average, the picture is disappointing. Although the curriculum statements in States/Territories generally provide a framework for a science curriculum focused on developing scientific literacy and helping students progress toward achieving the stated outcomes, the actual curriculum implemented in most schools is different from the intended curriculum. In some primary [elementary] schools, often science is not taught at all. When it is taught on a regular basis, it is generally student-centred and activity-based, resulting in a high level of student satisfaction. When students move to high school, many experience disappointment, because the science they are taught is neither relevant nor engaging and does not connect with their interests and experiences. Traditional chalk-and-talk teaching, copying notes, and*

> *"cookbook" practical lessons offer little challenge or excitement to students. Disenchantment with science is reflected in the declining numbers of students who take science subjects in the post-compulsory years of schooling. (Goodrum, Hackling, & Rennie, 2000, p. viii)*

Whilst science teaching and learning has experienced a considerable period of time in which it has been critiqued, there has also been extensive work around Standards for Teaching. Many State based accrediting authorities have seen their work encompassed by a new national body, the Australian Institute for Teaching and School Leadership (AITSL, 2012), which is charged with raising the status of teaching. Standards have been seen as one way to advance the 'status raising' objective and as such has had traction in Education systems across Australia for some time (see for example, Ingvarson, 1998). The Australian Science Teachers' Association (ASTA) certainly grasped the opportunity to lead in the work of standards development because they viewed it as an important professional issue:

> *There was no doubt in the minds of ASTA Council members ... that the primary responsibility for developing standards for good science teaching should rest with the teaching profession itself ... it was clear ... that the industrial relations setting is not a suitable place to do the hard, long term thinking about teaching and learning that must underpin the development of valid and challenging teaching standards. These standards must articulate deep educational values and give young teachers a clear direction in which to develop over the first ten to fifteen years of their careers. (Ingvarson & Wright, 1999, p. 29)*

The confluence of interest in science teaching and learning and professional standards has meant that science professional development has, not surprisingly, become a focal point. State and Federal policy development has been extensive as questions about 'the problem' (AEU, 2004; DEECD, 2009; DEST, 2003) and how it 'might be fixed' (DECD, 2011; DET, 2003, 2009) abound. However, at the heart of the issue lies an important point. There is a need to differentiate between Professional Development (PD) and Professional Learning (PL) in ways that go beyond rhetoric.

Exploring the nature of PD and PL

Grundy and Robison (2004) noted that, "By its very nature, teaching is never complete, never conquered, always being developed, always changing. … [However,] most of the practices that constitute trends [in PD] … are located within contradictory and contested spaces in educational discourse" (pp. 146 – 147). This view of contestation (especially in the Australian context) has been examined in detail by Hardy (2008, 2009, 2010) who reinforced Day and Sachs' (2004) description of PD as typically being viewed as top down, mandated change. Hardy (2010) asserted that PD tends to be dominated by, "individualistic, short-term and decontextualized activities, often in response to bureaucratic or administrative fiat" (p. 72) i.e., that PD is about doing things 'to teachers'.

It could well be argued that the domination of PD in the form of doing things 'to teachers' is as a consequence of the fact that teaching largely occurs in isolation with little if any chance (or expectation) for sharing or observation of practice with colleagues (Little, 1994). More so, the nature and organization of the daily teaching routine militates against reflection on pedagogical practice (especially as a shared activity). As a consequence, teacher development around such things as innovation in teaching and learning, curriculum change, and the development of new assessment policies and approaches is organized and structured around a PD approach based on a need for efficient delivery to maximize absorption by participants (Little, 1999). Such an approach stands in stark contrast to a professional learning (PL) perspective.

The notion of PL is different to that of PD because the impetus for learning, the approaches, support and intent are different to the traditional training model of development (Berry, Clemans, & Kostogriz, 2007). State and territory Departments of Education in Australia have begun to adopt the language of PL (DECD, 2011; DEECD, 2005; DET, 2009, 2012; NSWIoT, 2012), but unfortunately, the change in language does not necessarily equate with a shift in organization, structure or approach to programs/activities. However, where there is congruence, it is based on an acceptance that there is a need to "establish a self-directed, collaborative and dynamic culture of learning, and to build and develop the capability of staff to engage in such a culture of learning. Within this learning environment, staff take control of their own professional learning, integrating it into their daily work lives; their focus on improving outcomes for students" (DET, 2012, p. 1).

The DEECD (2005) articulated principles for PL that clearly differentiate between expectations derived of mandated change and doing things 'to teachers', as opposed to working 'with teachers'. Working 'with teachers' tends to be based on the view that there is a need to create conditions for teachers to work with, and be supported in, responding to their pedagogical issues, needs and concerns. In the early 2000s, as the PL approach to teacher growth and change came more into vogue, the Catholic Education Office Melbourne (CEOM) began to reconsider how, as an organization, it might better address their ongoing concerns about the nature of school science teaching and learning.

Identifying a need for action

The Catholic Education Committee of Victoria (CECV) identified Science as one of several key learning areas that required improved school and student performance (CECV, 2005). A Science Reference Group comprised of teachers, academics and school principals was established to report on specific issues and concerns related to science teaching and learning in schools. The reference group was charged with presenting an agenda for future directions for improvement. The Reference group raised five issues that it considered required attention:

(1) The nature of support from the school leadership team. (This included the time allocation for science coordinators to lead change, and the level of support for innovation and change in science teaching within schools.)

(2) The role of the science teacher/coordinator. (Issues included teachers' confidence in teaching science - particularly at the primary [elementary] level - and the role and status of the science coordinator and its impact on professional learning, mentoring and extension opportunities for science staff.)

(3) The standard of science taught - both content and pedagogy. (A major issue being that science curricula may not incorporate up-to-date content and pedagogy and science teachers may not always be aware of the range of resources available and the science activities possible. The conclusion being that when good

science teaching is neither valued nor facilitated, the standard of science taught is affected.)

(4) Student engagement in science, particularly in the middle years of schooling. (Recognition that teaching practices and curriculum are not always engaging, nor do they necessarily make links to relevant real-life situations for students or cater to different learning styles.)

(5) The needs of high-performing/gifted students. (It was evident that there was an inability to engage students of high intellectual or creative ability in science in some schools which contributed to the declining number of students completing senior chemistry, physics and biology.)

In responding to these issues from the Reference group, the CEOM commissioned the Centre for Science Maths and Technology Education (CSMTE) at Monash University to conceptualize an approach to developing science teachers' practice (both individually and collectively), through a Professional Learning program designed to challenge teachers' existing practice. The result was the Science Teaching and Learning project (STaL) which became a vehicle for challenging existing science teaching and learning practices by encouraging teachers to purposefully develop their knowledge of practice. In so doing, STaL aimed to redress some of the issues raised by the CECV about science education by focusing on the quality of science teaching within participants' own classrooms and did so by explicitly positioning teachers as "producers of sophisticated knowledge of teaching and learning, not just users" (Loughran & Berry, 2006, p. 15).

The STaL project was built on a belief that knowledge of practice is generated through experience (individual and shared) and that collaboration between teachers affords valuable opportunities for their professional learning. STaL embraced the idea that teachers are producers of specialised knowledge about teaching and learning, and that change in practice occurs most effectively when it is self-initiated and focused on individuals' pedagogical needs and concerns.

Teachers hold a rich knowledge about what they do, and this knowledge is continually being developed and refined; but it is not necessarily recognized or shared in other than ad hoc ways (Loughran & Berry, 2006). This is due to issues of organization (the busyness of teaching affords little time for teachers' contemplation of practice and school structures are rarely set up to promote learning from practice), and teachers' perceptions of their role (teachers rarely regard themselves as generators or holders of valuable knowledge about teaching beyond their individual classrooms, Loughran & Northfield, 1996). These aspects then influence how knowledge of practice is viewed and developed by teachers. Moreso, there is little expectation for teachers to engage in dialogue about teaching and learning or to move beyond sharing 'activities that work' (Appleton, 2002).

Central to the STaL project was a rejection of traditional notions of PD as the supply of pre-packaged knowledge to be distributed to teachers in 'easily digestible pieces'. A genuine focus on PL in accord with Lieberman's (1995) view that teachers should be actively involved in exploring their individual experiences and contexts and be supported to become articulate about what they have learnt was initiated. Conceptualized in this way, STaL as a PL approach, involved the sharing of insights about teaching and learning between teachers (as opposed to sharing activities that work) in order to gain a sense of professional control and ownership over their learning, and concomitantly, a responsibility for the learning and teaching environment that they create in their classes.

From this perspective, PL is clearly different to PD as it is concerned with empowering teachers through valuing their voices and perspectives (Gore & Gitlin, 2004). This is not say that teacher insights are the only effective form of educational knowledge - academic and other educational institutions also play pivotal roles in working with schools to offer different ways of knowing and looking at teaching practice (Jaworski, 2004). However, if valuing teachers' knowledge of practice matters, then ways of capturing it are crucial. To bolster approaches to knowledge development, STaL introduced, and took seriously, the development and use of Cases (Shulman, 1992). Cases were seen as a way of offering real possibilities for capturing, portraying and sharing participants' knowledge of practice because the format is 'real' i.e., teachers readily identify with cases as the dilemmas, issues and concerns on which they are based 'ring true' in meaningful ways. Case writing became a way of 'bringing to the surface' teachers' knowledge of practice in order to make the tacit explicit; for oneself and others.

Cases include the rich detail crucial to looking into practice in ways that are real to teachers. They capture what has happened, how and why in teaching and learning experiences. Hence, case writing and sharing - as developed and used in the STaL project - offered what Richert (1992) described as a means of promoting teachers' understanding of their experiences of teaching and learning. Therefore, the STaL project (culminating in a case writing day) was ultimately designed to support teachers' professional learning of their developing professional knowledge of science teaching and learning. (Subsequent sharing of their learning and professional knowledge also became possible through the resultant cases as a product.)

Structure and organization of STaL

STaL was developed as a consequence of a particular Federal Government focus on quality in Science Teaching and Learning with an emphasis on science teachers' professional development. However, the Professional Learning approach developed through STaL was as a consequence of the CEOM working within the policy environment to seek to do more than construct an 'add on' program. STaL became an appropriately (and consistently) resourced approach to developing and enhancing science teachers' professional learning (for detailed program structure, see Appendix 1).

All science teacher participants (approximately 35 per year) are volunteers (over time, STaL has developed a reputation amongst schools such that demand for the program is high). STaL places a premium on attracting pairs of teachers who work together in the same school (the notion of shared learning experiences and ongoing support through a 'buddy' system is a strong shaping factor in the organization of the program). As much as is possible, the program contains an even mix of elementary and secondary teachers. The program involves five days of formal workshops (2 x 2 day residential and 1 x 1 day) spread across a school year. The essential purpose of the program is to explore teachers' existing understandings of their practice and to introduce them to alternative ways of framing problems and reflecting on their practice and their students' learning – which is ultimately documented through their case writing.

During the course of the year, each teacher is supported by a member of the STaL academic team who visits participants in their school before the program begins, as well as before and after each program block. Through an ongoing process of school visits and electronic contact, a supportive relationship between STaL team members and participants is created which is important in assisting participants throughout the program. This relationship is developed with a particular emphasis on helping teachers to better conceptualize problems of practice specific to their teaching and learning context.

Each of the two-day components of the program explores different approaches to science teaching and learning and places participants in the role of being a science learner. In addition to these workshops, participants are also introduced to case writing as one way of conceptualizing, documenting, sharing and learning from practice. The final day of the program is a case writing day in which participants develop a case draft, share it with colleagues (STaL team members and participant teachers) in order to further refine their ideas and writing, and to more deeply reflect on their learning about science teaching and learning. For most participants, this is the first time in their teaching careers that they have had an organized and structured space established outside of their teaching to write about their practice. Cases are published as a book at the end of each program and copies of these books are given to all participants and shared within the Catholic Education schooling system. The Cases book is officially launched at the beginning of the STaL program the following year in which authors are invited back to receive their copies of the book and to share their experiences of STaL and case writing with incoming STaL participants.

An important feature of the program is an explicit valuing of teachers' time, energy and professional learning. For the vast majority of teachers, their experiences have been such that PD tends to be offered at times (after school or on curriculum days) and in places (most often schools) that implicitly suggest that their learning is a low priority for the system or a simple "add on" to their existing teaching duties. Further to this, although they often see more senior staff, principals and education bureaucrats involved in PD that is sponsored and conducted in more elegant or sophisticated surroundings, they are generally restricted to school sites and their programs tend to be "front loaded" to expose them to as much as is possible in a day. In contrast, STaL is conducted in a city hotel with all of the amenities and support afforded 'executive PD' and is fully funded by the CEOM. However, the individual schools are responsible for the cost of relief teaching to cover teachers' absence for the 5 days of the total program. In this way, teachers feel (for the first time) that their time, energy an involvement is valued and that what they are embarking on in STaL takes them, and their experience, seriously. (The same applies through the publication and official launch of their cases - in a book – and the fact that these books are distributed to schools across the CEOM.)

Overview of STaL program structure

- 5 day residential program conducted over a school year.
- 2 x 2 days, 1 x 1 day.
- Critical friend – visits all participants before the program and after each 2 day residential block (a very important role explained in detail later in the paper).
- Final day is a case writing day; cases are then edited, published, launched and celebrated. Participants receive copies of the case book and they are also used

by the CEOM, distributed to CEOM schools and a copy is sent to their principal.

- The program is organised in a city hotel not a school site. This has a high economic cost but illustrates a valuing of teachers and the nature of the PL on a scale they have never experienced in their work before.
- Participants (capped at 35) elementary and secondary science teachers, all volunteers, must have school leadership support, must be minimum of 2 participants per school (to develop ongoing shared experiences and support).
- Program has been conducted from 2005 – present.

Teaching in STaL

The STaL program is designed and taught by a team of Science Education academics from Monash University. The overall program is organized to help participants focus on their teaching and their students' learning and to culminate in their being able to articulate aspects of their developing professional knowledge of practice through case writing. Every session in STaL is team-taught with the expectation that both the teaching and learning is able to be 'unpacked' during sessions in ways that will draw attention to participants' evolving pedagogical issues, needs and concerns. To facilitate such interaction, participants are encouraged to use a journal to record their questions, ideas, issues, etc. during and after sessions, and as a record of the same for their practice in school between program days. Presenters work at two levels throughout the program. The first is in teaching the 'content' of the program, the second is in publicly reflecting upon and critiquing the teaching and learning during sessions (hence the importance of team teaching; sharing the teaching and reflecting/critiquing during a session is important to maintain engagement, responsiveness and relevance).

At the end of each day of STaL, a sharp debrief of the day's program is publicly conducted with a serious focus on the nature of the day's teaching and learning - what that might mean for participants' practice back in school, and the type of support, expectations, needs and concerns crucial to progressing a quality learning agenda.

Participating in STaL

Participants are purposefully confronted by challenging science learning situations; challenges of both subject matter content and pedagogy. Sessions are designed to explore a number of specific areas of science education, in particular, exploring students' existing ideas and alternative conceptions, promoting rich discussions among teachers themselves about learning, unpacking student thinking to explore student understanding, the role of effective assessment, the role of personal values in science education and scientific literacy.

The approach to both the teaching and learning in STaL is based on moving beyond an 'activities that work' approach. That means that teaching must be viewed (and conducted) as much more than just having a 'kit of good teaching tips and tricks'. Although it is important to have some routines in teaching, when teaching becomes overly 'routinized' elements of quality teaching e.g., engagement, enjoyment and intellectual challenge, may be diminished. The use of teaching procedures simply to break up the normal routine is not the same as choosing to use a particular teaching procedure for a particular pedagogic reason.

Pedagogical reasoning is important because it is a window into the underpinnings of practice. Therefore, seeing into a teacher's ability to adapt, adjust and make appropriate professional judgments in response to students' learning is helpful in understanding that teaching is not just about 'fun activities' or 'teaching procedures to break up the normal routine'. Understanding teaching as problematic, and conducting it that way, involves much more than 'pulling out something different from a bag of teaching tips and tricks'.

Expert pedagogues then are those that not only choose particular teaching procedures for particular reasons, but are also constantly developing their knowledge of practice in ways that allow them to see into teaching and learning with new eyes and to articulate the insights from so doing; for themselves and others. As a consequence, such teachers have a strong grasp of the notion of professional learning through actively developing their pedagogy. It is on this basis that all STaL sessions are organized, developed and conducted and the team teaching approach is specifically designed to 'unpack' the pedagogical reasoning and experiences of both the presenters and the participants in sessions.

The Science in the sessions is taught from a conceptual basis theoretically derived of the Big Science Ideas and prompts inherent in a CoRe for the particular topic under consideration (Content Representation, see Appendix 2 for an abbreviated example, Loughran, Berry, & Mulhall, 2006, 2012). Too often, Science is perceived (or actually experienced by students) as propositional knowledge that is delivered rather than being conceptually based, presenting opportunities for curiosity, creativity, questioning and engagement. By approaching science from a conceptual rather than propositional perspective (as per Big Ideas, see Appendix 2), content knowledge per se tends to gradually be understood by learners differently as they begin to engage with the ideas and possibilities for learning that are so different to being confined to only knowing facts, formulae and information.

Pedagogically, a conceptual approach to science also requires knowledge and experience of teaching and learning in ways that encompass the ability to recognize the need to be able to respond to the prompts of a CoRe (see Appedix 2). As a consequence, across the STaL sessions, CoRe prompts help to drive the pedagogical response to the teaching and learning being developed. These prompts are:

1. What do you intend the students to learn about this idea?
2. Why is it important for students to know this?
3. What else you know about this idea (that you do not intend students to know yet)?
4. What difficulties/limitations are connected with teaching this idea?
5. What knowledge about students' thinking influences your teaching of this idea?
6. What other factors influence your teaching of this idea?
7. What are the teaching procedures you use (and particular reasons for using these) to engage with this idea?
8. What are the specific ways you have of ascertaining students' understanding or confusion around this idea?

Clearly, not all prompts are able to be responded to in the same detail or to the same extent. The point is that they offer a framework for thinking about the development of science teaching and learning in ways that create a vision for pedagogical development and as a consequence, highlight key features of that which comprises a teacher's professional knowledge.

Conditions for change

As noted earlier in the paper, STaL is structured and taught in accord with principles of PL. At the heart of this approach is the need to place participants at the centre of science teaching and learning experiences so that there can be a serious and rigorous exploration of individual teachers' pedagogical issues and concerns and to be able to use these to drive development, inquiry and the articulation of professional knowledge of practice. However, there are a number of other elements that are important in shaping the conditions for change that go beyond solely applying a PL approach. (There is no particular order to the elements discussed below, rather it is that they exist, and that together, create an environment to support change.)

From an education systems perspective, there is little doubt that there is a major ongoing commitment by the CEOM, schools and participating teachers to the nature of the program. At each of these levels, there is an acceptance, even an embracing, of a PL approach which engenders an attitude and behaviours that create a predisposition to work with STaL as a meaningful program. As part of the system support, the funding has been consistent and despite some competing issues, has been sustained at the level necessary to ensure the program has not been diluted or compromised over time.

The participants, CEOM (through the Science Education Director and staff) and STaL program leaders work together as a team and have sustained strong working relationships. This relationship is evident at school level through the ongoing demand for the program and the manner in which schools have responded to the '2 or more participants from each school' expectation. Some schools (elementary in particular) have demonstrated ongoing commitment by being involved over a number of years and choosing to plan for the majority of their staff to be involved in STaL across the years.

School leadership support has been equally important and the expectations of that being more than token is reinforced through the work of the critical friend who, while visiting and working with participants, also meets with the principal about progress and development within STaL. The role of the critical friend is crucial. The skills, knowledge and ability necessary to perform this role appropriately cannot be underestimated. The critical friend functions in ways that allow for continual in school follow up and pushes teachers 'beyond stories' by thoughtfully and skilfully probing their experiences of 'pushing the boundaries' and experimenting with their science teaching to become more informed about practice.

STaL being structured as a residential program is also important. The presenters and participants all stay for the full duration of the program and share not only intellectually, but also socially; all of which enhances relationship building and illustrates a valuing of the experiences being created and reflected upon as a group enterprise. The fact that STaL is conducted in a city hotel (fully funded by the CEOM) makes explicit that participation is highly valued and that teachers are 'worthy of the expense' of such a venue.

The notion that PL should enhance the development of teachers' professional knowledge is encapsulated in the 'concrete output' of the program through the published cases. Case writing, although initially concerning for some participants –

writing being an expectation beyond their normal teaching duties and experience – is in fact a process that helps to focus participants' reflection on their practice and their students' learning. In so doing, participants become more adept at articulating their knowledge in a way that communicates their learning for themselves and others. The case writing day is a whole day program that is conceptualized around structured reflection on participants' science teaching and learning experiences and purposefully completes STaL with a focus on professional knowledge (see Appendix 3, chapter by Colquhoun, 2006, on her STaL experience). 'Teachers as published authors' is also a new experience for participants and carries, for them, a feeling of pride in their achievements in ways not normally associated with being a teacher.

Finally, the manner of involvement of the science education academics that teach in STaL has been noted by participants and the CEOM as a helpful attribute of the program that further creates conditions for supporting teachers' professional knowledge development. Participants come to value the link between teaching and research highlighted in STaL and (as noted in the final section of this paper), has helped to foster ongoing school based PL and research projects. In a real sense, the relationship building inherent in STaL places the research agenda 'on the table' and one outcome of that is that it reinforces the valuing of STaL because the university partner is viewed as active and interested in all aspects of the program.

Impact

The impact of STaL has, to date, not been studied in a systematic manner. The majority of the evaluative effort has been directed toward the ongoing development of the quality of the program. With that in mind, three outcomes stand out as most noticeable:

1. development of teachers' professional knowledge of practice;
2. leadership of science teaching and learning in schools; and,
3. research studies into the nature of the program itself (a full list of case books and other research publications based on STaL is included in Appendix 4 as an annotated bibliography).

Development of teachers' professional knowledge of practice

The focus of STaL is to develop deeper understandings of science teaching and learning in order to impact classroom practice. Case writing, the CoRe methodology, principles of PL and the notion of purposefully framing practice (see for example PEEL Baird & Mitchell, 1986; Baird & Northfield, 1992; and *What Expert Teachers Do*, Loughran, 2010) offer conceptualizations that productively shape participants' learning about science teaching and learning. The impact of such learning on participants is most evident in the published cases (see for example, Berry & Keast, 2009, 2010) that occurs at the end of the program each year. Teacher participants consistently demonstrate pride in their effort and a sense of valuing related to being a 'published author'.

The CEOM's ongoing financial support and the high demand from schools to be involved in STaL demonstrate a commitment that extends beyond the more typical mandated programs.

Leadership of science teaching and learning in schools

Beyond the individual pedagogical development of participants, the CEOM and schools view STaL as important for supporting the development of teacher leadership in schools in accord with the needs and expectations of the CECV Science Vision. The CEOM has developed stronger policy and practice around Science as a consequence of involvement in STaL. A leadership program for (existing and prospective) elementary school science co-ordinators (Contemporary Approaches to Primary Science: CAPS) has been developed and implemented. CAPS is viewed as a second phase of STaL in that it moves the focus more squarely onto elementary school science teaching and the 'in school leadership' needed to support that development. School wide impact of STaL has therefore been more noticeable in elementary schools than secondary schools. One reason being that the development of a critical mass of staff with a focus on science can impact an elementary school teaching program more readily than might be possible in secondary schools where subject departments tend to stratify (or isolate) subject matter teaching. As a whole school approach, some elementary schools have chosen to develop and implement their own school based PL to build on their STaL experiences (see for example, Loughran, Smith, & Berry, 2011; Smith & Howard, 2007; Smith, Loughran, Berry, & Dimitrakopoulos, 2011). In a similar vein, STaL and CAPS participants have shared their learning and taken leadership roles as they have moved and accepted leadership positions in science in other schools.

In the current round of National teaching awards, an elementary teacher who has participated in both STaL and CAPS and become an innovative and committed science leader has been nominated for the Prime Minister's award for excellence in science teaching. She has progressed through the rigorous selection process to become a finalist at the national level – a remarkable result (the final outcome is due in September 2013.)

Researching STaL

STaL has been researched and widely reported (see Appendix 4). However, despite the intensity of study into STaL a number of limitations exist. STaL has been organised and conducted on a small scale, it is a longitudinal and intensive program aimed at quality rather than quantity in relation to participant involvement and thus overall numbers. With respect to cost (approximately AUD$2500 per person), STaL does not easily configure to create a cheaper unit cost with increasing participant numbers as the structure of the program is based on many features (e.g., critical friend, intensive teaching and learning support) that increase with increased participant numbers. STaL has not been 'upscaled' due to the 'unit cost' per participant and the costs associated with attempting to increase the number of staff involved in working in the program. Despite these issues, there have been a number of important outcomes from researching STaL. For example:

1. National competitive research funding was awarded through the Australian Research Council (ARC) for a 3 year Linkage grant to study the ways in which STaL, as an innovative approach to Science Professional Learning, might catalyse teacher research in schools. That project led to insights into the nature of teaching for scientific literacy as documented through the book *Scientific Literacy Under the Microscope* (Loughran et al., 2011).

2. *Scientific Literacy Under the Microscope* was initiated by a group of elementary teachers who embraced STaL and pursued their teaching and their students' learning further in a whole school approach. Their teacher research into their approach to curriculum and pedagogical development combined with

the study of their students' learning illustrated well what could be done when a common approach to science was pursued through a whole school approach.

3. Research outcomes (book chapters and journal articles; see Appendix 4) from STaL have been captured through studies into: case writing; development of professional knowledge of practice; and, scientific literacy. These studies have demonstrated how the conditions for teaching and learning can be better understood and supported to impact school science.
4. Communicating with the profession. Cases have proved to be a valuable communication tool for teachers. The STaL Case books have created a great deal of interest within the profession for access to, and consideration of, teachers' knowledge of practice. A major teaching journal (*Teacher*) published by the Australian Council for Educational Research (ACER) re-presented many cases with an additional commentary to highlight participants' learning through STaL and the importance of that learning in relation to the development of teachers' knowledge of practice (see professional publications in Appendix 4).
5. The CEOM has lifted the profile of Science in schools in its own policy considerations. Despite the challenging economic environment, the CEOM has continued with a Science PL approach that continues to shape its expectations for teacher development and school practice (see, for example, http://www.ceomelb.catholic.edu.au/learning-teaching/science/science-projects/?terms=science).

Conclusion

STaL was initiated as a consequence of ongoing concerns about the quality of school science teaching and learning. The program developed was constructed on principles of PL and sought to eschew the features of mandated PD so commonly experienced by teachers. Such PD is stereotypically viewed by teachers as having little relevance to their classroom needs and concerns and has little impact on their professional knowledge of practice.

STaL has demonstrated that science teaching and learning can be well supported if a serious commitment to PL and teacher knowledge remains at the centre of the enterprise. Scaling up such a program has its challenges and linking teachers' learning to enhanced student learning outcomes is equally demanding. Although it stands to reason that enhanced teacher knowledge should lead to improved student learning outcomes, it is not necessarily a linear relationship simply discernible through a cause and effect model.

Effective teacher professional growth is complex mirroring the complexity of teaching and learning. Just as pedagogical development and change is sophisticated business, so too is the creation, construction and delivery of professional learning. In many instances, teachers experience PD that is mandated, top-down and heavily policy directed rather than pedagogical driven. When those conditions change and appropriate resourcing and valuing follows, teachers' professional knowledge is able to be well developed to help create more informed, thoughtful and committed science teachers.

References

ACARA. (2010). National assessment program: Science literacy year 6 report. Sydney: Australian Curriculum and Assessment Authority.

AEU. (2004). AEU response to Australia's teachers: Australia's future: Advancing innovation, science, technology and mathematics: Committee for the review of teaching and teacher education. Southbank, Melbourne: Victoria: Australian Education Union, www.aeufederal.org.au/Publications/2004/RespteachAct2.pdf.

AITSL. (2012). Australian professional standards for teachers Retrieved 1st May, 2013, from http://www.teacherstandards.aitsl.edu.au/

Appleton, K. (2002). Science activities that work: Perceptions of primary school teachers. *Research in Science Education*, *32*(3), 393 - 410.

Baird, J. R., & Mitchell, I. J. (Eds.). (1986). *Improving the quality of teaching and learning: An Australian case study - The PEEL project*. Melbourne: Monash University Printing Service.

Baird, J. R., & Northfield, J. R. (Eds.). (1992). *Learning from the PEEL experience*. Melbourne: Monash University Printing Service.

Berry, A., Clemans, A., & Kostogriz, A. (Eds.). (2007). *Dimensions of professional learning: Identities, professionalism and practice*. Dordrecht: Sense Publishers.

Berry, A., & Keast, S. (Eds.). (2009). *Looking into practice: Cases of science teachers' professional growth (Vol. 1)*. Melbourne: Monash University and the Catholic Education Office Melbourne.

Berry, A., & Keast, S. (Eds.). (2010). *Looking into practice: Cases of science teachers' professional growth (Vol. 2)*. Melbourne: Monash University and the Catholic Education Office Melbourne.

CECV. (2005). Improving science teaching and learning. Seminar 6, June, 2005. *http://www.cecv.melb.catholic.edu.au/reseminar/seminars5-8/seminar6.pdf*

Colquhoun, Y. (2006). Cases: A teacher's perspective. In J. Loughran & A. Berry (Eds.), *Looking into practice: Cases of science teaching and learning* (2nd ed., Vol. 1, pp. 11 - 14). Melbourne: Monash University and the Catholic Education Office Melbourne.

Day, C., & Sachs, J. (2004). Professionalism, performativity and empowerment: Discourses in the politics, policies and purposes of continuing professional development In C. Day & J. Sachs (Eds.), *International handbook on the continuing professional development of teachers* (pp. 3–32). Maidenhead: Open University Press.

DECD. (2011). Discussion paper two: Supporting our teachers: Recognise, respect and value. Adelaide: Department for Education and Child Development, http://www.decd.sa.gov.au/aboutdept/files/links/SupportingOurTeachers.pdf.

DEECD. (2005). Professional learning in effective schools: The seven principles of highly effective professional learning. Melbourne: Department of Education and Early Childhood Development https://www.eduweb.vic.gov.au/edulibrary/public/staffdev/teacher/induction/ProfLearningInEffectiveSchools.pdf.

DEECD. (2009). Energising Science and Mathematics Education in Victoria Strategy: Blueprint implementation paper. Melbourne: Department of Education and Early Childhood Development http://www.education.vic.gov.au/about/programs/learningdev/Pages/sciencemaths.aspx.

DEST. (2003). Australia's teachers: Australia's future: Advancing innovation, science, technology and mathematics: Committee for the review of teaching and teacher education. Canberra: Department of Education, Science and Training.

DET. (2003). Blueprint for government schools: Future directions for education in the Victorian government school system. Melbourne: Department of Education and Training http://www.education.vic.gov.au/Documents/school/teachers/profdev/proflearningeffectivesch.pdf.

DET. (2009). Education Queensland professional development plan for state schools 2010-2012. Brisbane: Department of Education and Tranining, Queensland http://education.qld.gov.au/staff/development/pdfs/pd-plan-2010.pdf.

DET. (2012). What is professional learning? Retrieved 26/05/13, 2013, from www.education.nt.gov.au/__data/assets/.../WhatIsProfessionalLearning.pdf

Goodrum, D., Hackling, M., & Rennie, L. (2000). The status and quality of teaching and learning of science in Australian schools. Canberra: DETYA http://intranet.onec.go.th/world_ed/sciencereport.pdf

Gore, J. M., & Gitlin, A. D. (2004). [RE] Visioning the academic-teacher divide: power and knowledge in the educational community. *Teachers and Teaching: Theory and Practice, 10*(1), 35 - 58.

Grundy, S., & Robison, J. (2004). Teacher professional development: Themes and trends in the recent Australian experience. In C. Day & J. Sachs (Eds.), *International handbook on the continuing professional development of teachers* (pp. 146-166). Maidenhead: Open University Press.

Hardy, I. (2008). Competing priorities in professional development: An Australian study of teacher professional development policy and practice. *Asia-Pacific Journal of Teacher Education, 36*(4), 277-290.

Hardy, I. (2009). The production of Australian professional development policy texts as a site of contest: The case of the federal quality teacher programme. *Australian Educational Researcher, 36*(1), 73-88.

Hardy, I. (2010). Critiquing teacher professional development: Teacher learning within the field of teachers' work. *Critical Studies in Education, 51*(1), 71-84.

Ingvarson, L. (1998). Professional development as the pursuit of professional standards: The standards-based professional development system *Teaching and Teacher Education, 14*(1), 127-140.

Ingvarson, L., & Wright, J. (1999). Science teachers are developing their own standards. *Australian Science Teachers' Journal, 45*(4), 27 - 34.

Jaworski, B. (2004). *Grappling with complexity: Co-learning in inquiry communities in mathematics teaching development.* Paper presented at the Proceedings of the 28th Conference of the International Group for the Psychology of Mathematics Education, Volume 2, 17-36, http://www.emis.de/proceedings/PME28/PL/PL003_Jaworski.pdf.

Lieberman, A. (1995). Practices that support teacher development. *Phi Delta Kappan, 76*(8), 591-597.

Little, J. W. (1994). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis 15*, 129-151.

Loughran, J. J. (2010). *What expert teachers do: Teachers' professional knowledge of classroom practice*. Sydney, London: Allen & Unwin, Routledge.

Loughran, J. J., & Berry, A. (Eds.). (2006). *Looking into practice: Cases of science teaching and learning.* (2nd ed. Vol. 1). Melbourne: Monash Print services.

Loughran, J. J., Berry, A., & Mulhall, P. (2006). *Understanding and developng science teachers' pedagogical content knowledge*. Rotterdam: Sense Publishers.

Loughran, J. J., Berry, A., & Mulhall, P. (2012). *Understanding and developng science teachers' pedagogical content knowledge* (2nd ed.). Rotterdam: Sense Publishers.

Loughran, J. J., & Northfield, J. R. (1996). *Opening the classroom door: Teacher, researcher, learner*. London: Falmer Press.

Loughran, J. J., Smith, K., & Berry, A. (2011). *Scientific literacy under the microscope: A whole school approach to science teaching and learning*. Rotterdam: SENSE.

Mitchell, I. J., & Mitchell, J. (Eds.). (1997). *Stories of reflective teaching: A book of PEEL cases*. Melbourne: PEEL publishing.

NSWIoT. (2012). Continuing professional development policy: Supporting the maintenance of accreditation at the level of proficient teacher/professional competence. Sydney: NSW Institute for teachers, http://www.nswteachers.nsw.edu.au/Continuing-ProfessionalDevelopment/CPD-Policy/

Rennie, L., Goodrum, D., & Hackling, M. (2001). Science teaching and learning in Australian schools: Results of a national study. *Research in Science Education, 31*, 455 - 498.

Richert, A. E. (1992). Wrting cases: a vehicle for enquiry into the teaching process. In J. H. Shulman (Ed.), *Case Methods in Teacher Education*. New York: Teachers College Press.

Shulman, J. H. (1992). *Case methods in teacher education.* New York: Teachers College Press.

Smith, K., & Howard, M. (Eds.). (2007). *Bringing Science to Life - A Reflection of Classroom Practices in Science at Our lady of Good Counsel Parish Primary School Deepdene.* Melbourne: Our lady of Good Counsel Parish Primary School Deepdene & the Catholic Education Office Melbourne.

Smith, K., Loughran, J. J., Berry, A., & Dimitrakopoulos, C. (2011). Developing scientific literacy in a primary school. *International Journal of Science Education, 34*(1), 17-152.

Appendix 1: STaL program

Science Teaching and Learning Program

Program Block 1 – DAY ONE

Date/Time		***What***	***Purpose***
Day 1	8.00-9.15	**Registration, tea, coffee**	
	9.15-10.45 **(1hr 30min)**	Introduction 10 mins (max) 1) INTRODUCE JOURNAL 2) POE on air pressure and start to unpack teaching and learning approach to lead into the next session and the approach to STaL generally.	Overview of STaL Explain point of reflection/journal Provide a starting point for the teachers to consider new ways of thinking about science teaching and learning.
	10.45–11.00	**Morning tea**	
	11.00-1.00 **(2.0 hrs)**	Science Topic Floating and Sinking *Emphasize importance of investigation combined with reflection.* *(use journal entries for review and examination of teaching and learning experiences)*	Create a strong episode to offer ways of thinking about Science teaching and learning. Challenge participants to think about impact on their own practice. Discuss importance of enquiry learning using a range of approaches from problem based learning to discovery learning. Encourage a journal entry for participants to record their thinking and questions raised by this session.
	1.00-1.45	**Lunch**	
	1.45 - 3.30 **(1hr 45min)**	Introduce science topic "Water" and explore the diverse range of responses it generates. Use a Lotus diagram - Where is the science? - Generating student questions?	Highlight how this frames the task as more 'manageable' particularly when dealing with topics/ideas that may be challenging. Ensure the approach encourages student questioning and ways of working with these in productive ways.
	3.30 – 4.00 **(30 mins)**	Reflecting on the frames and insights from the day and drawing links to "something significant for my practice": "What was it like to be a learner?" "What does this mean for my understanding of my students as learners?"	To consider the frames presented during the day and how they might be useful. Highlight insights gained and link to "What does this mean for being a Science leader?" Use 3, 2, 1 as a reflection tool for capturing ideas.
	6.00 – 7.00	**Drinks & Canapé**	*Social Event + previous STaL participants and CEOM guests.*
	7.00 – 9.00	**Dinner & Book launch with guests from previous year's program**	*Cases Book Launch & case writing discussion from past participants.*

Program Block 1 – DAY TWO

Date/Time		What	Purpose
Day 2	**9.00 – 10.30** **(1hr 30min)**	Why values in Science?	Create a strong case for the importance of values in Science. *Build in reflection (encourage journal entry); challenging session for participants.*
	10.30-11.00	**Morning Tea**	
	11.00-12.00 **(1 hr)**	*Science Literacy* What is it? Why is it important? How can it be addressed in your class and at a school level? Introducing a web based resource to gain awareness of the ideas behind scientific literacy, (its contentions, limitations, use of, etc.) including notions of *science for all*, *science for active citizenship,* etc.	Introduce participants to the ideas that underpin the importance of building science literacy. To see how other teachers' practice promotes certain values of science as a way into considering scientific literacy in the classroom. *Build in reflection time for potential uses of the resource* *(encourage journal entry).*
	12.00 – 1.00	**Lunch**	
	1.00-1.40 **(40min)**	Working with the DEECD Science Continuum P-10. The value of considering students' alternate views & the current scientific view. Developing ways of thinking and working differently in science teaching.	To illustrate how to use the continuum and ways of working with it to reconsider the nature of teaching and learning and overall pedagogical purposes in science teaching in a "useable" way. *(encourage journal entry)*
	1.40 -3.00 **(1hr 20 min)**	Different approaches to unpacking students' understanding in School Science	To make the links between teaching, learning and assessment in science more explicit and to illustrate alternative approaches to ascertaining where students are at. *Build in reflection* *(encourage journal entry)*
	3.00 – 3.30	Debrief and thanks to participants and CEO. Remind about in school follow up from critical friend and 'homework' for next part of program.	Use 3, 2, 1 as a reflection tool.
	3.30	**Depart**	

Program Block 2 – DAY ONE

Date/Time		What	Purpose
Day 3	**8.00-9.15**	**Book into Hotel Registration etc.**	Registration, tea, coffee
	9.15 – 11.00 **(1hr 45min)**	Welcome and review of inter session tasks/building possibilities for teacher research: what did we learn? - What becomes problematic? - What caused you to change your practice?	Make strong links to experimenting with practice and learning from that to see into teaching and learning science in new ways. *Build in reflection* *(use sessions journal)*
	11.00– 11.20	**MORNING TEA**	
	11.20–12.50 **(1 hr 30min)**	What is Science? The concept of evidence.	To explore how teachers can challenge the nature/purpose/role of science and how it has been traditionally taught in schools. To consider the teacher notions of science and the concept of evidence in ways that may help them to reconsider the way they are presenting science to their students and the impact this may be having on their teaching practice.
	12.50 – 1.40	**LUNCH**	
	1.40 - 3.00 **(1hr 20min)**	CASES what do they look like? "What does it mean to trial something significant in your classroom?" **Context - distance/time graphs:** Do the activity and reflect on the event, then read the case, consider the activity, deconstruct and reconstruct the case to highlight important points that make the case so strong.	To illustrate what a case is, how it is constructed and the messages it can send out to a reader. Also, to make explicit how a case is drawn from "meaningful issues" of practice. Try to show how to move beyond describing an activity and getting at the insights into knowledge of practice *Build in reflection* *(use sessions journal)*
	3.00 – 4.00 **(1 hr)**	Leading Change: Issues, Barriers and concerns for teacher researchers.	Highlighting the difficulties of leading change and ideas about how to make progress individually and as a group. Use Head, Heart, Bin, Bag, as a reflection tool.
	6.00 – 7.00	**Drinks & Canapé**	**Everyone**
	7.00 – 9.00	**DINNER**	**Everyone**

Program Block 2 – DAY TWO

Date/Time		What	Purpose
Day 4	**9.00 - 10.40** **(1hr 40min)**	Exploring a science issue to examine why Scientific Literacy should be valued. - Why has science evolved to be done the way it is? - What are the strengths of a scientific approach? - Why is the research on climate change so hotly disputed given the research evidence is so strong?	Develop an understanding of the advantages of a scientific approach and its effectiveness at reducing human biases. **Use Climate Change video** Use the frames of scientific literacy to examine the issue and better understand its impact.
	10.40- 11.05	**MORNING TEA**	
	11.05–12.45 **(1 hr 40min)**	Slowmation	Create another way of thinking about how to explore science teaching and learning. Give a concrete example and develop skills in doing slowmation. An opoportunity to specifically link to CoRe prompts.
	12.45 – 1.35	**Lunch**	
	1.35 - 3.05 **(1hr 30min)**	Slowmation – Group presentations. What does the experience mean for building a case?	Reflect on the activity and start to draw out the important insights that would be helpful for sharing learning with other science teachers. *Build in reflection* *(use sessions journal)*
	3.05 – 3.30 **(30 min)**	Setting up for interim tasks and possibilities, outline plan for ongoing support. Thanks to participants and CEO	Making strong focus on “significant episode” and creating an expectation of doing something different in participants’ own classes. Use 3, 2, 1 as a reflection tool.
	3.30	**Depart**	

Day 5: Case writing day

Time	Activities	
9.00 – 9.30	Registration (Tea & Coffee).	
9.30 – 10.45	Overview of the day. One person's journey so far (participant presentation from strong case writing possibility). Sharing your case ideas in triplet groups. Aim to identifying key ideas and critical teaching and learning issues.	
10.45 – 11.00	Morning Tea/Coffee & Refreshments	
11.00 – 12.30	Case writing & drafting time. Monash staff available for reactions & assistance as needed. Keep circulating, being available and model support and thoughtful critique (not criticism of writing, help develop ideas and strength of portrayal).	
12.30 – 1.15	Lunch & Refreshments	
1.15 – 2.30	When appropriate, pair up and read one another's case and offer your reactions and feedback to one another to help refine the case. Continue case writing & drafting as needed. Monash staff continually available for reactions & assistance.	
2.30 – 2.45	Afternoon Tea/Coffee & Refreshments	
2.40 – 3.00	Review of progress so far. Difficulties and strengths of the case writing process. Final writing and collection of case files on a USB thumb drive for editing and formatting for publishing. All final cases to be double checked with authors prior to publishing. *(Ensure your case has been collected)*	

Appendix 2: CoRe (Content Representation), abbreviated example

This Core is designed for students in Middle Secondary School, i.e., Year 10.	IMPORTANT SCIENCE IDEAS/CONCEPTS			
	It is useful to explain the circulatory system using the model of a continuous closed system	**The circulatory system functions to service the needs of individual cells**	**Body systems are very dependent on each other for their proper functioning**	**Blood is a complex substance**
What you intend the students to learn about this idea.	The blood circulatory system includes the heart, blood and blood vessels. Blood is contained within closed vessels. …	All living things require a means of transporting nutrients to, and wastes away, from cells. Individual cells each require nutrients …	Body parts and systems are interdependent. Damage to one system/part will affect, to some extent, all others. …	Blood is composed of cells, cell fragments, liquid plasma and dissolved substances. …
Why it is important for students to know this.	Increased understanding of body processes is likely to lead to increased personal responsibility for particular behaviours …	Because cell life and death affects the whole organism. …	Even though the blood circulatory system is a 'closed circuit', it requires exchange with other systems for 'life' to be maintained.	
What else you know about this idea (that you do not intend students to know yet).	Details of the circulatory systems of other kinds of living things e.g., insects, plants. …	Details of the supply of energy through chemical reactions in cells. …		
Difficulties/ limitations connected with teaching this idea.	Models and drawings (e.g., cells/systems) are idealized representations. Limitations of the 'closed-system' … some materials pass (in and out) across barriers.	There can be confusion about what "waste" means e.g., CO_2 is not generally thought of as a waste. The idea that individual cells supply body needs is difficult.	How 'smaller' systems link together to form bigger systems (e.g., excretory and digestive system). …	Blood parts and types are made in different parts of the body. The idea that nutrients and waste are carried in solution can be difficult for students.
Knowledge about students' thinking which influences your teaching of this idea.	Students don't often have a sense of continual movement of blood. Even with knowledge of capillaries, they often don't realise they are connected in a circuit.	Ideas about 'waste' are more likely to be connected with digestive system. Students do not think of gases as possible wastes.		
Other factors that influence your teaching of this idea.	Students enjoy learning about themselves.			
Teaching procedures (and particular reasons for using these to engage with this idea).	**Question Building** through 1:1 discussion: Students explain to each other (in pairs) what each knows about the human circulatory system and develop a list of questions/issues they would like to know more about.	**Ask questions:** why do we eat/ breathe? **Students draw** onto a body outline the pathway of a marshmallow showing any changes that occur as it moves through the body.	**Road transport analogy:** Students develop a detailed analogy of the circulatory system as a road transport system that includes important parts of other systems.	The availability of curriculum kits that examine issues such as transplantation, transfusion, heart surgery etc.
Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).	Students write agree or disagree next to statements then explain their thinking. …	When students are discussing macro actions (eating etc.) with needs of cells, the teacher listens carefully for their ability to make links between the two.	Listening for links between digestive and circulatory system.	

Appendix 3: Chapter from cases book

Cases: A teacher's perspective[1]

Yvette Colquhoun
Trinity College, Colac

The CEO/Monash *Science Learning and Teaching Program* that I, and the other authors of the cases in this book were involved in, was an invaluable experience that gave us an opportunity to reconnect the importance of teaching with purpose. Too often we (teachers) are overwhelmed with course content which relentlessly drives the quality and depth of information delivered to students. This program gave us time out from the daily demands of school to personally reflect on our teaching from cognitive and practical perspectives. It provided a wide range of practical strategies to encourage and nurture the importance of what students already know and to build on this in a purposeful way. An issue that we were all reminded of was the importance of valuing students' prior knowledge, experiences and perceptions, and how we can create an atmosphere where students are able to be supported in their learning so that the learning experience becomes meaningful for them and quality learning becomes a reality.

As educators we regularly make assumptions about what students bring into the classroom. These assumptions primarily impact on our lesson planning, influencing the path of learning we perceive that needs to be created. But how well do we construct this path to really meet the students' learning needs? Do all students have the opportunity to integrate their prior views into their learning as the topic progresses? And, are there alternatives for students to extend and diverge from the pre-ordained path to self-direct and develop their own learning path with support and encouragement from the class?

The sessions we were involved in encouraged us to personally reflect on and, as a consequence, to affirm what in our practice was successful and to identify areas in our teaching which could be strengthened through trialling alternative teaching procedures and strategies. It also highlighted the importance of using the partnership with students to gain constructive feedback – they are often the best critics! – and to refine our practice.

The small workshop environment available through the project encouraged a friendly and supportive forum through which teachers from a wide cross section of schools could share their understandings of practice. The sessions explored a diverse range of learning contexts and teaching procedures which could be used with students to encourage them to express their understanding of the content under consideration. Often, participating in these sessions caused many conflicting thoughts and challenges amongst the group, creating some significant insights into the effects our teaching has on the development of our students' learning.

Being a learner of teaching

Participating in the classes from a student perspective really provided a vital insight into the difficulties of expressing one's knowledge clearly, applying it to a question and being confronted by the challenge of committing to expressing ones' own understanding of particular science content in a group situation. The internal conflicts that students face in developing their learning and the importance of extending their prior views were emphatically demonstrated and felt by all.

This highlighted the careful planning needed by educators to support students through this often delicate and risky extension of understanding publicly and to ultimately facilitate the growth of confidence and enthusiasm in learners to broaden their knowledge.

[1] **Source:** Colquhoun, Y. (2006). Cases: A teacher's perspective. In J. Loughran & A. Berry (Eds.), *Looking into practice: Cases of science teaching and learning* (2nd ed., Vol. 1, pp. 11 - 14). Melbourne: Monash University and the Catholic Education Office Melbourne.

From a teacher's point of view, it is challenging to relinquish control at times and allow students' discussion to persist or to extend the time available for a group activity. Even though we can mediate the discussion and direct it to a purpose, or structure group activities and circulate through the class monitoring their development, teachers feel a constant pressure to push through and complete all the work. This dilemma raised the important issue of the 'ultimate wait time' (a Case from the PEEL book we worked with, see Mitchell & Mitchell, 1997) and the extent to which wait time can be a constraint in the learning process. Through this case, we discussed the issue of creating time for students to reflect on the effectiveness of a lesson and how more time needs to be provided to students to identify and collate their thoughts through a structured activity. Work on cases like this therefore became important in shaping how we developed our own case (see section 2 of this book).

Between sessions there was time to reflect on the discussions and issues raised back within our own school context. Many of us repeated a few of the teaching procedures that were used with us to gauge student reactions and feelings. It was useful to refresh our teaching senses - we could empathise with their discomfort on open ended questions, appreciate their contributions to the group when probing prior views and see the interest and satisfaction in solving or refining a concept.

From these sessions we were provided with a wealth of teaching procedures and reflections from teachers who were examining their practice. It was encouraging to read their experiences and see that there is not one individual on a lone professional journey but many people sharing the richness of their experiences and offering advice from real teaching practice. Of course each teacher must enter into their own journey to genuinely refine and develop their own craft but the value of sharing this and adapting advice from others to better our practice is priceless. This also became an important issue in shaping what we did when we developed our stories of our practice in our cases.

Doing cases

From sharing our experiences with the group, we were empowered to recognise and affirm the collective knowledge that we, as practising teaching professionals, could also contribute by sharing our knowledge drawn from our classroom encounters with others. This led to engaging in teacher research and the formulation of cases that documented our classroom experiences. I have to say, that doing cases does appear to be very daunting at first but the essential thing to note with formulating a case is that it is really only formalising and extending that which we already do as professionals on a day to day basis. We are constantly refining our craft, not every change is a monumental teaching moment but anything that causes you to think, "Yes, that was a good lesson, getting the students to re-create a scenario in groups allowed them to see the idea more clearly," is a case waiting to be written. Often the staff room debriefs with a colleague on an informal level provide excellent food for thought and avenues for writing something that may help other teachers. That's how each of these cases were written - we wrote about personal powerful experiences which gave us insights into the teaching and learning of our students with the intention that, as others read them, they might be encouraged to do something similar.

The presenters of this program offered a wonderful support base. They were all friendly, enthusiastic and passionate about their teaching and the vibe about promoting effective teaching and learning was contagious. During the case writing each of us was supported by a mentor from the Monash team who encouraged and guided us in deciding on a case to write about. Many of us also received visits to our school which enabled us to further elaborate on our ideas one on one and also show what was happening in science in our own settings. Gaining exposure to this level of support was amazing and valued by all participating in the program. The reflections and thoughts from our research cumulated in a case writing day which provided us with the time to collate our thoughts and write the articles. During this time we swapped and shared our stories with other teachers and the Monash team who provided constructive feedback and the draft of this book was created.

In preparing this chapter, I re-read the cases and was struck by how identifiable they are as everyday scenarios - the ideas, the student dialogue and the evaluation of successes and failures in day to day teaching are evident throughout. I felt as though any of these cases could have been in my class as it is so easy to relate with the teachers and students as the themes and issues discussed resonated so well with me.

Using cases

With a collection of cases such as these it is envisaged that other teachers might be inspired by our experiences and identify with the challenges faced. We don't make claims to be teaching experts or to theorise about the best activity for communicating a particular topic. Our cases are of our experiences and are situated in where each of us is in our current journey in teaching. We are in the classroom everyday, some activities work, others are complete disasters and through these trials we become better educators. It is not expected that teachers will integrate every idea or suggestion raised in these cases but hopefully one or two will challenge others to look at their own teaching and perhaps be extended by choosing to try something that is out of their comfort zone – push the upper level of their teaching skills. In so doing, there is a genuine satisfaction in engaging students in learning and strengthening relationships with them as a collaborative learning community for teacher and student. John Eason's case (*Understanding the human body: The effect of drugs*) demonstrated the reward of creating life-long learners 4 years after the learning had taken place!

From my experience in the program it has really enabled me to refocus on the importance of good teaching and the vital role it plays in nurturing the development of our students. We want learning to be a positive experience, to encourage students' curiosity and support their investigation of the world around them in a meaningful way. They need to extend their understanding in a supportive environment and be provided with the mental space and forum to communicate their learning in a variety of ways. It is impossible to engage and plan for every individual student as much as we would like to! But, by incorporating a diverse range of activities and teaching procedures, we are providing them with the best opportunities to participate and develop.

The use of cases is not intended to force you to change your teaching, instead it is hoped these cases will encourage an ongoing refinement of teaching practice so that the personal professional journey that each of us must take includes being a learner of the teaching craft. Working on this program and writing cases has supported me in becoming more perceptive about the purpose and knowledge that underpins my teaching, to actively reflect on the learning taking place and to provide thought for improving my pedagogy by urging me to actively do something about a teaching procedure or strategy that isn't achieving the desired outcome. In other words, it helped reinforce for me the idea – don't be frightened of trialling something new.

Reflecting on teaching

In teaching, we need to celebrate and share more in other teachers' successes, to adapt new ideas that might suit our own teaching environment and provide depth of meaning to our personal curriculum delivery. As a science coordinator, I feel that sharing these cases with my faculty could encourage greater collegial discussion about our current teaching practices. We don't take enough pride in the activities that work well for us. Seldom do we sit down as a faculty and discuss how a concept is taught or what procedures are used. As with the case that Kirstie and I wrote (*The question: What is light?*) two different methodologies resulted in one group retaining the information while the other, who understood it more initially, not retaining it in the long term. We need to acknowledge and tap into the wealth of teaching knowledge and experience which is already in our faculties and rate this as an important and essential aspect of our meetings. Having access to a hands-on resource such as this book could stimulate valuable discussion that is practically relevant to the questions: "Where is our teaching currently at and what are we doing about it? Is it working? How can I/we make it better?" On the one hand these appear simple questions, on the other, responding to them can lead to a powerful improvement in teaching.

Participating in this program has clearly identified for me the lack of collegial opportunities we have in school to share our knowledge of practice but it has also prompted me to recognise and acknowledge the depth of experience available within schools. We have possibilities around us all to tap into the resources available. You could record a personal journal of your teaching experiences, discuss a specific concept with a colleague – how do they teach it? - document dialogue with students and review it later, ask students for their feedback on a lesson. Any of these strategies could be incorporated into your teaching program to varying degrees and will encourage and support effective teaching and learning and provide richness to your teaching journey and experience. The opportunity is yours. Take advantage of it!

Appendix 4: Publications from STaL

Commercial book:

Loughran, J.J., Smith, K., & Berry, A. (Eds.) (2011). *Scientific literacy under the microscope: A whole school approach to science teaching and learning.* Dordrecht: Sense publishers.

A study into the work of a group of teachers in one school (many of whom authored chapters in the book) about their teacher research in relation to teaching for scientific literacy. Teachers involved were all STaL 'graduates' who pursued their own learning in new ways in their school as a consequence of their experiences in STaL.

Non-Commercial books:

Keast, S., Lancaster, G., Loughran, J.J., & Panazzon, D. (2013). *Understanding teaching and learning science through cases.* Monash University & the Catholic Education office Melbourne: Monash Print Services.

Keast, S., & Loughran, J.J. (2012). *Exploring scientific literacy: Through cases of teaching and learning.* Monash University & the Catholic Education office Melbourne: Monash Print Services.

Berry, A., & Keast, S. (Eds.). (2009). *Looking into practice: Cases of science teachers' professional growth (Vol. 1)*. Melbourne: Monash University and the Catholic Education Office Melbourne.

Berry, A., & Keast, S. (Eds.). (2010). *Looking into practice: Cases of science teachers' professional growth (Vol. 2)*. Melbourne: Monash University and the Catholic Education Office Melbourne.

Loughran, J.J., & Berry, A. (Eds.) (2008). *Looking into practice: Cases of science teaching and learning Volume 3.* Melbourne: Monash Print Services/Catholic Education Office (Melbourne).

Loughran, J.J., & Berry, A. (Eds.) (2007). *Looking into practice: Cases of science teaching and learning Volume 2.* Melbourne: Monash Print Services/Catholic Education Office (Melbourne).

Loughran, J.J., & Berry, A. (Eds.) (2006). *Looking into practice: Cases of science teaching and learning.* Melbourne: Monash Print Services/Catholic Education Office (Melbourne).

Cases books from derived of the STaL program. These books comprise almost 250 cases into science teaching and learning, analysis and insights.

Smith, K., & Howard, M. (2007). *Bringing science to life*. Melbourne: Catholic Education Office.

A school based science teaching and learning cases book developed by participants of STaL from one school working with their colleagues.

Book chapters:

Loughran, J.J., & Smith, K. (In press). Changes in science teaching that lead to changes in science learning. In Debbie Corrigan, Justin Dillon, Alister Jones and Richard Gunstone (Eds). *The future in learning science and what's in it for students.* Dordrecht: Springer.

Meta-analysis of teachers' insights into students' science learning as derived from their written cases.

Crawford, B., Lederman, J., Lederman, N., Luft, J., Loughran, J.J., Smith, K., Berry, A.,Tan, A-L., Lim, S.S., & Van Driel, J. (In press). What is the evidence for effective professional development for teaching science as inquiry? In Catherine Bruguière, Pierre Clément, and Andrée Tiberghien (Eds.). *ESERA 2011 Selected Contributions. Topics and trends in current science education.* Dordrecht: Springer Press.
Brief overview of philosophy and structure of STaL with specific reference to inquiry.

Loughran. J.J., & Berry, A. (2011). Making a case for improving practice: What can be learned about high quality science teaching from teacher produced cases? In Corrigan, D., Dillon, J. & Gunstone, R., (Eds). *The Professional Knowledge of Science Teachers*, (pp. 65 - 82). Dordrecht: Springer.
Study into the development of teachers' knowledge of practice as evident through case writing experiences.

Loughran, J.J., Smith, K., & Berry, A. (2010). Researching the development of science teachers' contemporary understandings of scientific literacy. In Ingo Eiks & Bernard Ralle (Eds.). *Contemporary science education: Implications from science education research about orientations, strategies and assessment. (pp. 147 – 156).* Germany: Shaker Verlag.
Analysis of elementary teachers' approaches to enhancing their teaching of scientific literacy.

Loughran, J.J. (2007). Teacher researcher projects. In Kathy Smith and Mary Howard (Ed.), *Bringing science to life (pp. 6 – 10).* Melbourne: Catholic Education Office.
Response to teacher directed approaches to professional learning about science in an elementary school.

Refereed journal articles:
Smith, K.V., Loughran, J.J., Berry, A., & Dimitrakopoulos, C. (2011). Developing scientific literacy in a primary school. *International Journal of Science Education, 34 (1),* 127 – 152.
Research into multi-domain approach to teaching for scientific literacy. The multi-domain approach was developed by a group of teachers who pursued their learning from STaL further in their elementary school in an attempt to impact students' learning at a whole school level.

Berry, A., Loughran, J., Smith, K., & Lindsay, S. (2009). Capturing and enhancing Science teachers' professional knowledge. *Research in Science Education*, 39(4), 575-594.
Understanding the ways in which STaL influences teachers' professional knowledge development.

Professional Journals
Loughran, J.J., & Lindsay, S. (2011). Time to stop and think. *Teacher, 5* (3), 54 – 55.
Loughran, J.J., & Lindsay, S. (2011). Shared control and learning. *Teacher, 5* (3), 10 – 11.
Keast, S., & Cooper, R. (2010). Linking for learning. *Teacher, 4* (4)
Keast, S., & Cooper, R. (2010). Independent learners. *Teacher, 4* (3)
Keast, S., & Cooper, R. (2010). Doing the opposite leads to success. *Teacher, 4* (2)
Keast, S., & Cooper, R. (2010). Thinking about thinking. *Teacher, 4* (1)
Keast, S., & Cooper, R. (2009). Another string to your bow. *Teacher, number 207*
Keast, S., & Cooper, R. (2009). Less is more. *Teacher, number 205*
Berry, A., & Keast, S. (2008). Risky business. *Teacher, number* 192.

Lindsay, S., & Loughran, J.J. (2008). Cases of science teaching and learning. Facing the fear and doing it anyway. *Teacher, March, 189, 34 - 37.*

Lindsay, S., & Loughran, J.J. (2008). Cases of science teaching and learning. Under pressure. *Teacher, February, 188, 36 - 39.*

Lindsay, S., & Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. Learning lights up. *Teacher, December, 187, 36 - 39.*

Lindsay, S., & Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. Out of my comfort zone *Teacher, November, 186, 36 - 39.*

Lindsay, S., & Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. What was I trying to do again? *Teacher, October, 185, 36 - 39.*

Lindsay, S., & Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. Adaptation. *Teacher, September 184, 58 - 61.*

Lindsay, S., & Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. Hands on chaos. *Teacher, August 183, 64 - 67.*

Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. Pandemonium or busy, engaged learning?. *Teacher, May 180, 55- 57.*

Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. Understanding the human body: The effect of drugs. *Teacher, April 179, 52 – 55.*

Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. Building conceptual bridges. *Teacher, March 178, 58 – 60.*

Loughran, J.J. (2007). Looking into practice: Cases of science teaching and learning. The Particle Model. *Teacher, February 177, 52 – 54.*

Loughran, J.J. (2006). Looking into practice: Cases of science teaching and learning. Marching through solids, liquids & gases. *Teacher, December 176, 56 - 59*

Australian Council for Educational Research (ACER) journal (*Teacher*) sought to share the case learning experience within the profession in ways that would be applicable, meaningful and useful to other teachers.

National Competitive Research Grant:

Loughran, J.J., Berry, A., Corrigan, D., Keast, S., & Mitchell, I. (2009 - 2011). *Science teacher research* ($380,000). Australian Research Council.