Understanding and Developing Science Teachers’ Pedagogical Content Knowledge

2nd Edition

John Loughran, Amanda Berry and Pamela Mulhall

Monash University, Clayton, Australia

and

University of Melbourne, Australia

There has been a growing interest in the notion of a scholarship of teaching. Such scholarship is displayed through a teacher’s grasp of, and response to, the relationships between knowledge of content, teaching and learning in ways that attest to practice as being complex and interwoven. Yet attempting to capture teachers’ professional knowledge is difficult because the critical links between practice and knowledge, for many teachers, is tacit.

Pedagogical Content Knowledge (PCK) offers one way of capturing, articulating and portraying an aspect of the scholarship of teaching and, in this case, the scholarship of science teaching. The research underpinning the approach developed by Loughran, Berry and Mulhall offers access to the development of the professional knowledge of science teaching in a form that offers new ways of sharing and disseminating this knowledge.

Through this Resource Folio approach (comprising CoRe and PaP-eRs) a recognition of the value of the specialist knowledge and skills of science teaching is not only highlighted, but also enhanced. The CoRe and PaP-eRs methodology offers an exciting new way of capturing and portraying science teachers’ pedagogical content knowledge so that it might be better understood and valued within the profession.

This book is a concrete example of the nature of scholarship in science teaching that is meaningful, useful and immediately applicable in the work of all science teachers (preservice, in-service and science teacher educators). It is an excellent resource for science teachers as well as a guiding tool for teacher education.

Understanding teachers’ professional knowledge is critical to our efforts to promote quality classroom practice. While PCK offers such a lens, the construct is abstract. In this book, the authors have found an interesting and engaging way of making science teachers’ PCK concrete, usable, and meaningful for researchers and teachers alike. It offers a new and exciting way of understanding the importance of PCK in shaping and improving science teaching and learning.

Professor Julie Gess-Newsome
Dean of the Graduate School of Education
Williamette University

This book contributes to establishing CoRe and PaP-eRs as immensely valuable tools to illuminate and describe PCK. The text provides concrete examples of CoRe and PaP-eRs completed in “real-life” teaching situations that make stimulating reading. The authors show practitioners and researchers alike how this approach can develop high quality science teaching.

Dr Vanessa Kind
Director Science Learning Centre North East
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Professional Learning
Volume 12

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Rationale:

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.
Understanding and Developing Science Teachers’ Pedagogical Content Knowledge

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2nd Edition

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The authors are grateful for the research support made possible through funding from the Australian Research Council.
The first edition of this book was published six years ago. Since then, we have been involved (individually and collectively) in an array of activities derived from the interesting range of possibilities and ideas that CoRes and PaP-eRs have created both for us and for others. We have had the good fortune to be invited to share our ideas with colleagues internationally (e.g. New Zealand, USA, Canada, UK, Taiwan, Hong Kong, Singapore, Sweden and the Netherlands) as teachers and researchers have engaged with CoRes and PaP-eRs as a framework for thinking about practice. Through researching PCK, new and innovative projects have sprung up in many places in ways that have more than demonstrated the allure of the concept to the research community (Hume & Berry, 2010; Nilsson & Loughran, 2010, 2011). Now, as we release this second edition of the book, we take the opportunity to add to our existing Resource Folios, by offering a very different approach to a CoRe with accompanying PaP-eRs on the topic of Genetics (see chapter 9). We have also added some interesting explorations and interpretations of the value and use of CoRes and PaP-eRs from users’ and researchers’ perspectives.

In this preface to the second edition we now briefly explain how our thinking has developed over time as a consequence of engaging with the construct of PCK, and the understandings that have emerged for us through working with CoRes and PaP-eRs, as both a process and a product.

Initially, we did not realise what we were getting ourselves into when we began to explore what ‘pedagogical content knowledge’ really means, what it looks like in practice, and how it might be captured and portrayed for others.

In the first instance, the idea of PCK was enticing because it seemed to be such a clever way of imagining what the specialist knowledge of teaching might involve. PCK conjured up an image of cutting-edge knowledge of practice, something special and important, something that could define expertise, something that could illustrate in a meaningful way why teaching needed to be better understood and more highly valued. However, much to our surprise, when we started researching PCK, we found that “seeing” PCK proved to be exceptionally elusive. The teachers with whom we worked struggled to understand what we meant by the term. We found it difficult to ask questions that could “unpack” their specialist knowledge of practice (although we were convinced it existed); and, while we thought we knew what we were doing, we struggled to make progress.

Over time, we slowly developed the CoRe (Content Representation) framework as a consequence of engaging with the construct of PCK, and the understandings that have emerged for us through working with CoRes and PaP-eRs, as both a process and a product.

The CoRe framework created a coherent way of conceptualizing science content that reflected (for us) the inherent knowledge of practice that we saw in expert teachers but which they themselves so often struggled to articulate. PaP-eRs (Pedagogical and Professional-experience Repertoires) were developed as a natural consequence of the need to dig deeper into the myriad aspects of the CoRe in order to capture the essence of teachers’ pedagogical reasoning and purpose; to make the tacit explicit.

The synergies between CoRes and PaP-eRs were immediately obvious to us as we put them together into a package which we called a Resource Folio. When we assembled our first complete Resource Folio (Particle Theory – see chapter 4), we felt as though we had learnt a great deal about that special amalgam of content and pedagogy that Shulman (1986, 1987) so eloquently described as pedagogical content knowledge, all those years ago.

As we progressed and developed a number of other Resource Folios (see chapters 4–9; chapter 9 being new to this edition) we became increasingly aware of the special and intriguing nature of PCK. Researching PCK had a dramatic impact on our understanding of practice. As we attempted to capture and portray PCK, we were confronted by our own lack of particular science content knowledge on many occasions. As a consequence, we were reminded of how limited understandings of a specific topic inhibit the ability to create the amalgam of content and pedagogy that is PCK. In addition, the essence of PCK is not captured by mere representations of teachers just “knowing what to do” or “how to do it”.

Over the course of our long research adventure with PCK, our own views about what PCK is and how it might be described and explained for others have gradually changed as we have become better informed about the idiosyncrasies of the construct. This is not least because of the issues, problems and concerns it created for us in our work.

Just as PCK has captured our attention, it has also done the same for others. The allure of the PCK construct is immediately obvious in the literature where, from time to time as the cycle of interest ebbs and flows, refinements, reconsiderations and adjustments to Shulman’s original notion rise and fall. We have found that some of these “additions” have been less than helpful in clarifying the nature of PCK, and in some cases, actually make it more confusing.
We contend that PCK is more conceptual than concrete, and that there is a learning curve about PCK that influences how researchers interpret and use it. For example, it is not unusual to hear of subject-specific PCK – which we would see as tautological. In a similar vein, some describe context specific or context dependent PCK – again, a somewhat redundant use of a signifier. There are also those instances of particular content being injected into the term such as that of TPCK (Technological Pedagogical Content Knowledge), and conversely, even that of generic and specific PCK. On the one hand it seems as though the more that PCK is refined and/or redefined in a bid to make it more concrete, the less valuable it becomes as a descriptor of specialist or expert knowledge of practice. But on the other hand, in its more conceptual form it is almost too abstract to be practical.

In reflecting on our research efforts with PCK (through the development of CoRes and PaP-eRs), we seem to have been caught between the abstract and the concrete, although that is not necessarily a bad thing. The CoRe captures not just an individual’s thinking about the teaching and learning of specific content but, also, the collaborative or shared understandings of that content across groups of teachers. On the other hand, PaP-eRs are very specific to a particular aspect of the CoRe and therefore quite distinctive and individual. We came to the view that for a given topic, CoRes and PaP-eRs necessarily combine to illustrate what PCK might involve, but no single aspect of them alone defines PCK. We sought to make PCK concrete through CoRes and PaP-eRs, but also acknowledge the importance of it as an abstract construct; and, we reject our methodology being characterized as a recipe for, or a competency list of, PCK.

It is hard to know now, but perhaps we subconsciously responded to what Shulman described as the generative nature of PCK (Berry, Loughran, & van Driel, 2008a): as we came to understand it better, the need to fully “pin it down” became less important, despite the fact that insights into the nature of PCK were crucially needed. So in many ways, we arrived at a point where being able to illustrate instances that might safely be described as indicative of PCK was more important to us, than categorically stating that something was PCK. Nevertheless, even though CoRes and PaP-eRs, as packaged in a Resource Folio, are very concrete, they also carry strong conceptual underpinnings that allow for a diversity of interpretations and applications. One such variation is through the ways in which teachers have engaged with them.

When we started our research we were very conscious of our own science teaching roots and our desire to do something that would be useful for teachers. We had often bemoaned the difficulties of teachers of finding research outcomes that were applicable in their classroom practice (see for example, Berry & Milroy, 2002) and so pushed ahead with our PCK research in the hope that we might do something to address the issue. However, over time, we found ourselves feeling caught between the needs, expectations and requirements of academia (and research funding) and our concerns for outcomes that would be meaningful for science teachers. From time to time we lamented that our work might appear to be theoretically strong but practically soft. So we were a little surprised, but certainly pleased, when we observed what teachers and teacher educators did with CoRes and PaP-eRs.

Although we did not develop CoRes and PaP-eRs as curriculum documents, many teachers immediately translated them into that form. They used (in particular) CoRes as a way of reconsidering what science content could look like, how it might be arranged and what it meant to organise curriculum conceptually, rather than in a linear fashion. PaP-eRs were a little more challenging. They liked to read them and to interrogate what was being portrayed, but usually found constructing them to be time consuming and not so valuable from a personal perspective (see Adam Bertram’s chapter – another addition to this edition). Hence, the value to teachers was in terms of encouraging reflection on practice, creating a shared language for discussing science teaching and learning, and offering insights into practice, all of which became a springboard for their own professional learning.

Some teacher educators, as illustrated in particular by the work of Jim Woolnough, incorporated the teaching of PCK into their science teacher education programs. Jim used CoRes and PaP-eRs to help his student teachers see learning about science teaching in ways that challenged the more typical student teacher need to scramble for “tips and tricks” to build a bank of fun activities (Woolnough, 2009). Jim used CoRes and PaP-eRs as a way of teaching his student teachers about being science teachers, not transmitters of science information. Together, they worked on constructing their own CoRes and PaP-eRs before, during and after their practicum (school experience) in a way that created a vision for what their ongoing professional learning might look like as science teacher specialists. Jim’s research into his use of PCK as a development goal in learning to be a science teacher demonstrated how his approach to science teacher education changed along with his student teachers’ understanding of, and expectations for, science teaching.

Now, as we complete this edition of the book, we see new possibilities emerging from our work. These new possibilities have come about as a consequence of teachers and teacher educators being attracted to the concept of PCK as an idea, and to CoRes and PaP-eRs as one way of making that idea useable in practice. As is always the case with quality teaching, truly expert teachers (Loughran, 2010) grasp the essence of new approaches to pedagogy and interpret, alter and adjust those ideas and practices to meet their purposes in their classrooms with their students. They create new ways of thinking about the content, their students’ learning and their own development as professionals. We believe that CoRes and PaP-eRs create these types of opportunities for teachers and hope that this book continues to be useful in the day to day practice of science teachers, teacher educators and researchers.
CHAPTER ONE

TEACHING

Learning through experience

I had an awakening … I had taught science in five different high schools … believing I was a very good teacher. … At the time I believed I had ‘mastered’ teaching, because I knew my science content as well as having accumulated a large repertoire of teaching strategies and hands-on activities. … Over time, my self-perception as having ‘mastered’ teaching slowly dissolved. … I progressively became aware that my teaching of high school science over 14 years was rather mundane … Upon reflection, I realized that, as a secondary science teacher for 14 years, I knew my science content but very little about how children learn. … Thus began my awakening about understanding the complex relationships between teaching and learning that is still evolving today. … In retrospect … I had such a simplistic conception of teaching during those first 14 years; it is a little embarrassing that I believed I had mastered the job. (Hoban, 2002, pp. xvi - xvii)

Teaching is complex work and like Garry Hoban (above), many teachers come to find that their initial simplistic views of teaching are confronted when the intricacies of their work become clearer over time. Through this process, whereby a growing understanding of teaching begins to emerge largely as a result of learning through experience, a new appreciation of one’s skills and abilities compels some to move beyond the simple delivery of information.

This, however, is not as straightforward as it may sound, as a strong and pervasive view of teaching is based on a transmissive model whereby prescribed content or information is delivered to students. Through this transmissive model, the approach of content “delivery” is often misrepresented as that which comprises teaching.

A transmissive view of teaching is in stark contrast to perceiving teaching as a process of enhancing learning through developing a deeper understanding of content, whereby teaching procedures and strategies are selected for particular reasons that are important to shaping learning in ways that are meaningful and valuable to the learner. Clearly then, there are major differences in the implications for teachers, and teaching, when a transmission model is contrasted to the complex model of teaching for understanding, through which expertise in pedagogy is genuinely viewed as skilfully managing (and enhancing) the relationship between teaching and learning.

PROFESSIONAL LEARNING

Just as Garry Hoban experienced an awakening in relation to his views of and subsequent approaches to teaching, for many teachers there are ongoing and subtle reminders of the mismatch between their intentions for teaching and the practice that evolves as a consequence of the dailiness of teaching (Loughran & Northfield, 1996). However, even though the distinction between delivering content and teaching for understanding may be apparent, choosing to do something about it is a completely different matter.

Unfortunately, approaches to professional learning that might encourage teachers to more readily respond to the inherent contradictions between intentions and actions in teaching are not necessarily supported at either a school or systemic level. Therefore, for those who choose to respond, the professional learning journey is often characterised by individual teachers finding themselves questioning their own practice and seeking new ways of constructing teaching and learning experiences without necessarily being supported, encouraged, or rewarded for so doing.

For example, the work of Mandi Berry and Philippa Milroy (2002) demonstrates how difficult it can be to approach teaching science in ways that draw on notions of acknowledging and responding to students’ prior views and purposefully addressing alternative conceptions. They set out to ‘teach in ways that would better facilitate students’ better understanding of science concepts; foster students’ responsibility for their own learning; and, work from the position that science is a social process and that science ideas change over time’ (Berry & Milroy, 2002, pp. 196 - 197).

Attempting to meet such aims obviously confronts the notion of teaching as the transmission of information. However, in attempting to address these concerns, Mandi and Philippa found it to be demanding work. There was little real support available to them within their school and, perhaps more surprisingly, even less advice and direction in the educational research literature. Therefore, they were left
to work through their issues alone and to construct their teaching in new and different ways, whilst simultaneously implementing such changes in their classrooms. They found themselves inventing and implementing, devising and trialling whilst also managing the day to day concerns of teaching the ‘prescribed’ curriculum.

What Mandi and Philippa then came to recognize was that the changes in their teaching comprised a journey, not an event. They did not teach one way at the start of their adventure and then suddenly transform their teaching overnight to become new and different teachers. They came to develop their teaching as they experimented with their practice and built new understandings of teacher and student learning. Their journey involved many false starts, much frustration, considerably more work and time and the development of new scripts that challenged their previous routines in teaching science. Their professional learning, while being personally rewarding, was not something able to be garnered from a book on curriculum reform, or developed as a result of an in-service or professional development activity. Rather, their professional learning was as a consequence of choosing to consistently pursue deeper levels of understanding of science with their students, and sharing, documenting, and reflecting together on their efforts whilst also seeking evidence of quality learning from their students. In a real sense, they came to learn more about their skills as teachers and what to do to enhance those skills in strengthening the relationship between teaching and learning.

Moving beyond activities

One of the major changes associated with developing views of teaching, that seems important in the type of shift that both Hoban (2002) and Berry and Milroy (2002) reported is linked to a recognition that teaching is much more than just having a “kit of good activities”. Although it is important to have some routines in teaching, when teaching becomes “routinized”, elements of quality teaching (e.g. engagement, enjoyment and intellectual challenge) can be dramatically diminished; or worse, absent all together. Therefore, developing helpful routines whilst not allowing teaching to become routinized is a tension that many teachers experience; a similar situation is equally pertinent in terms of learning.

It is not difficult to see how there can be a natural tendency for teachers to incorporate a range of teaching procedures (e.g. concept maps, Venn diagrams, role-play, interpretive discussion, etc.) into their practice in order to break-up the “normal routine”. However, 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. This issue goes to the heart of what it means to be an expert pedagogue: one who chooses to use a particular teaching procedure at a particular time for a particular reason, because, through experience, that teacher has come to know how teaching in that way enhances student learning of the concept(s) under consideration. Such pedagogical reasoning is important because it is the thinking central to creating a path through complex teaching and learning situations. It is a window into the thoughtful and skilful act of practice that is responsive to the given context, i.e. there is not the assumption that the same thing works the same way all of the time. The ability to adapt, adjust and make appropriate professional judgments, then, is crucial to shaping the manner in which teachers teach and respond to their students’ learning.

Clearly then, understanding teaching as complex, interwoven, and problematic is at odds with transmissive views of teaching which inevitably trivialize and undersell the skills, knowledge, and ability evident in the practice of expert teachers. The use of a range of teaching procedures to break up the normal routine, even though at times apparently effective (because of the break from the predictable routine), does not in itself mean that transmissive views of teaching do not still dominate a teacher’s practice. The shift to understanding teaching as problematic, and practising it that way, involves much more than “pulling out something different from a bag of teaching tricks”. This point is perhaps best demonstrated through the work of PEEL (Project for Enhancing Effective Learning) teachers.

PEEL (Baird & Mitchell, 1986; Baird & Northfield, 1992; Loughran, 1999) is an example of a movement in education that directly responds to teachers’ concerns about students’ passive learning; which itself is partly a consequence of “traditional” teaching. PEEL teachers view teaching as problematic and have become expert at developing teaching procedures that are the antithesis of transmissive teaching. The accumulated wisdom of practice evident in their work (shared and disseminated through a diverse range of meetings, conferences, and publications) is driven by their desire to challenge students’ passive learning habits in order to develop their metacognitive skills, and to therefore become more active, purposeful learners. As a consequence, PEEL teachers’ knowledge of teaching is such that it demonstrates how thinking about teaching as something more than the delivery of information, is a foundation to strong, ongoing professional learning.

As an experienced PEEL teacher, Rosemary Dusting (2002), offered an extensive examination of her efforts to move from teaching as telling to teaching for understanding. In so doing, she captured the essence of the challenge associated with genuinely confronting, and moving beyond, transmissive approaches to teaching.
The method I adopted to teach Mathematics was the same as I experienced at school. … Therefore, on my first school appointment, no option for teaching Mathematics had been demonstrated to me other than the traditional exposition model – the teacher in total control of all the knowledge. … I suppressed memories about how certain teachers made me feel idiotic if I ventured a response that was incorrect, or how others barely even noticed whether there were students in class … Initially I tried to perfect the exposition style and to develop a repertoire of methods to keep students quiet whilst I told them what they needed to know. Thus the type of questions I asked myself about the quality of my teaching and my students’ learning tended to be restricted to blaming myself – or the students – for any perceived lack of success. I had a sense of responsibility for making students understand and remember. It was my problem. I had to show them what to do. If I did not show them properly, then they would not learn and I would have failed. (Dusting, 2002, pp. 174 – 175, emphasis in original)

In the first instance, Rosemary was confronted by the incongruity of her teaching and her expectations for students’ learning, and so found the use of engaging teaching procedures as helpful in breaking her students’ passive learning routines. However, over time, she also came to see the need to go beyond teaching procedures alone and to better link her teaching to her expectations for her students’ learning.

I was [now] attempting to more consistently teach for understanding … I began to ask myself reflective questions … [and] metacognition became important and deepened my understanding of my teaching. … As I watched students learning this way [through PEEL procedures] I genuinely felt that I had created circumstances in which there was engagement with the task, concentration, active student involvement, risk-taking and increased interest. My teaching had shifted from me doing all the work for the students to the students now working out part of the content for themselves. They had been provided with meaningful opportunities to think and I had not taught by telling. … My understanding of what it meant to teach students to be active learners was being developed and I valued what was happening. (Dusting, 2002, pp. 177 - 180)

In a similar way, Vivienne Sullivan (1996) came to see how the relationship between teaching and learning converged when her use of teaching procedures was carefully considered and the implications of such practice applied to not only the way she taught, but how she reflected on and planned for her teaching. With a group of others at her school, she was part of a teacher-initiated examination of the use of teaching procedures, in order to better understand how those procedures influenced students’ learning, as well as their own teaching practice. What these teachers did was to adopt an approach to examining their use of teaching procedures, discussing and writing about them using a simple but powerful formula. They considered the aim of their particular lesson, the method (i.e. teaching procedure) used to implement the aim, the observations they made of their students’ learning, and then evaluated the process as a whole to extract new insights about teaching and learning: they were extending their knowledge of their wisdom of practice.

In considering the use of the POE (Predict-Observe-Explain) teaching procedure in a science class, Vivienne noted that:

The “Explain” part of the exercise was well written by about one third of the students. They tackled the conceptual errors that they had experienced in the “Predict” phase, and showed some real progress in their understanding of the experiment. … others who had predicted inaccurately wrote explanations of their errors … The effectiveness of the exercise as a learning tool was discussed with the students and feedback sought. It was judged by the majority of the class to have required more thought on their part than if the demonstration had just been shown to them. I feel confident that this is the case. (Sullivan, 1996, p. 32)

What is clear in the extract (above) is that the manner in which her students appear to be thinking about the content is dramatically different from that which would normally be the case if the content were simply being told or “delivered” to them. Even more so, it is clear that the students are also involved in considering their own learning as tackling their conceptual errors and explaining their own inaccurate predictions, behaviours that have much more to do with constructing genuine understanding as opposed to knowing what the teacher said.

This approach to better understanding the use of teaching procedures and the articulation and development of the wisdom of practice demonstrates how understanding teaching as being problematic requires a major shift in a teacher’s thinking and subsequent practice. The fundamental shift is from a view that teaching can make students learn, or, as Rosemary Dusting described it, ‘a sense of responsibility for making students understand and remember’ (p. 175), to finding ways of encouraging students to accept more responsibility for their own learning.

Accepting responsibility for learning requires students to be aware of what they are doing and why, to question their own learning, and to build their knowledge by (at least) processing, synthesizing and linking the new ideas and concepts with those they already possess. In so doing, their new knowledge is a
step forward in them actively developing deeper understandings of concepts/content being studied. Such acceptance is encouraged through teaching that creates meaningful opportunities for students to be engaged in constructing and restructing their own knowledge. By the same token, it is not difficult to see that although teaching may often be misconstrued by some as the simple delivery of information, the reality is that quality learning cannot be mandated, or as Jeff Northfield explained it when reviewing a year of his teaching of Year 7, *quality learning requires learner consent* (Loughran & Northfield, 1996, p. 124).

The expert pedagogue, then, is one that not only chooses particular teaching procedures for particular reasons, but is 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 others. Without doubt, such teachers have a strong grasp of the notion of professional learning through actively developing their pedagogy.

Developing pedagogy

Pedagogy is a term that is used in education in a variety of ways and, to some, can appear to be a buzz word, or a form of jargon, designed to make talk of teaching appear more sophisticated and remote from real world practice. In many instances (particularly when considered in places such as the U.S.A., Canada, U.K., and Australia) it is often used as a synonym for teaching. However, using pedagogy in that way weakens the real meaning of the term.

Drawing on the European tradition, pedagogy has more to do with understanding the relationship between teaching and learning in ways that foster children's development and growth. Van Manen (1999) eloquently describes pedagogy:

> As a practice, pedagogy describes the relational values, the personal engagement, the pedagogical climate, the total life-worlds and especially the normativity of life with children at school, at home, and in the community. And as an academic discipline, pedagogy problematizes the conditions of appropriateness of educational practices and aims to provide a knowledge base for professionals …

Central to the idea of pedagogy is the normativity of distinguishing between what is appropriate and what is less appropriate for children and what are appropriate ways of teaching and giving assistance to children and young people. (p. 14)

Therefore, in considering carefully what *developing pedagogy* might mean for teachers, it becomes immediately apparent that it entails considerably more than accumulating a “bag of teaching tricks”. Although there is clearly a need for teachers to be familiar with, and capable of using, a range of teaching procedures, it is equally important that their use alone is not seen as an end unto itself. Hence, in developing their pedagogy, teachers are working as professionals to better understand, create and respond to the appropriate conditions through which educational practice might be enhanced and through which their professional knowledge might grow. In all of this, a concern for students and their learning is at the heart of the endeavour.

Viewed from this perspective, telling is not teaching and listening is not learning. Rather, the fluency with which teachers adopt, adapt and adjust practices to create conditions for learning matters in creating strong and meaningful links between teaching and learning that highlight the real meaning of pedagogy. And, for teachers who approach their work in this way, development of pedagogy is an ongoing aspect of their professional life. As briefly noted earlier, Jeff Northfield demonstrated such an approach in his examination of his teaching of Year 7. In so doing, he sought to learn from his experiences.

Learning from experience

Jeff Northfield, an experienced teacher, teacher educator and educational researcher, wanted to experience what it was like to be a PEEL teacher in a school. He therefore chose to stand aside from his teaching and research responsibilities at a university for a year in order to pursue his ambitions for his high school teaching. In so doing he accepted a teaching allotment that allowed him to teach the same class (Year 7, first year of high school) for science, mathematics and home group. Through the possibilities inherent in such an allotment, he was able to examine his understanding of developing pedagogy and to create possibilities for learning from experience in ways that created new insights into teaching and learning for him and substantially shaped his professional learning.

One of the insights that Jeff gained was about the notion of “breaking set”. He used the term to:

> … describe the acceptance of the adjustments and changes he needed to make as a teacher as he learned to teach in a different context. Breaking set was part of his need to accept responsibility for what the class did and how they did it. … he recognized that the students had a view of classrooms, what they had to do and how they had to do it and it was one with which they were comfortable – it was generally teacher centred. Students listened, did what was necessary, and the proceedings
would come to a halt at the sound of the bell. Any departure from the ‘set’ could lead to a favourable response if it was an enjoyable variation from the ‘set’, but for the students this could not become part of the set as it did not constitute real school learning; it was viewed with some suspicion. Jeff’s concern was to find the right time and level of trust to introduce activities which required thinking and encouraged acceptance of responsibility for their own learning. He found it difficult when he moved from the ‘set’ (expected classroom approach) … ‘breaking set’ placed him in a less certain classroom environment, yet one that he was in fact seeking. (Loughran & Northfield, 1996, p. 32)

An important insight into the notion of breaking set is that it applies equally to both teacher and students. Routinized practice quickly becomes the “set” in teaching and so “breaking set” can create unforeseen challenges as the teacher moves from a sense of confidence in, and knowledge of, particular practice to a riskier situation characterised by uncertainty and a heightened consciousness of learning about practice through a new situation.

For students, the same obviously applies. The sense of comfort and confidence that comes with knowing the routine can quickly dissipate when the expectations for learning shift as a consequence of teachers using approaches to teaching with which students are unfamiliar. The change in expectations associated with changes in teaching and learning can therefore be quite unsettling for some and engender a response of covert resistance.

For a teacher attempting to change the expectations of, and conditions for, learning in the classroom, this resistance may be misinterpreted as students lacking the ability to work in a given way or for the quality and/or quantity of their perceived learning to be diminished as a result of ‘breaking set’. However, what Jeff came to understand about this type of situation was the need to respond appropriately to the changes in expectations so that both the teacher and the students were clear about the shift in the purpose of learning. From his experience, he recognized that students needed to understand what it felt like to be active rather than passive learners, and as a teacher he needed to feel what it was like to persevere with teaching procedures that impacted the status-quo.

Success could only really be achieved when both the teacher and the students accepted that ‘breaking set’ led to positive learning outcomes, and that entailed more than simply enjoying the experience or having fun. Genuine quality learning was recognized as requiring effort and was very different from the ‘busy work’ that is stereo-typical of regular school learning.

Recognizing and responding appropriately to the issues associated with breaking set then becomes important in coming to terms with the ongoing effort and commitment necessary to teach (and learn) for understanding.

Jeff Northfield’s journey offered him substantial opportunities for professional learning that, of themselves, could not be created or delivered through traditional professional development or in-service activities. Professional learning was about learning from, and building on, experiences and involved sustained reflection on practice, and a search to understand and construct new meaning by looking into situations from different perspectives. This ability to frame and reframe (Schön, 1983) is important for seeing teaching as problematic and for instituting ways of approaching practice that will challenge the view of teaching as telling and learning as listening. It is enmeshed in searching for multiple paths, and purposefully developing different entry points into learning through a dynamic interchange between knowledge and the process of building knowledge, as opposed to delivering static information.

WORKING FOR CHANGE

Many teachers experience the sense of unease or dissatisfaction in their teaching when they feel as though they have taught something well but their students do not seem to have learnt it as well as they initially believed. Recognizing such situations is a reminder of the problematic nature of teaching, and can also be a beginning point for teachers choosing to challenge entrenched routines. Changing practice is not easy. However, the outcomes for professional learning can be the driving and sustaining force in maintaining the effort. And maintaining the effort appears to be linked to new ways of conceptualizing content, teaching and learning. Consequently, through professional learning the need to be better articulate one’s own learning about practice encourages the development of a language for sharing such knowledge. One aspect of such language can be described in terms of pedagogical content knowledge.

Similar to the term pedagogy, pedagogical content knowledge (PCK) can at first appear to be jargon. However, through linking the construct with the actual experience of exploring and examining the relationship between teaching, learning and content, PCK not only takes on a new and significant meaning, but also opens professional practice to scrutiny in ways that highlight the skills, knowledge and abilities of teachers who think about their teaching in ways that are purposeful, instructive and inextricably linked to understanding the intricacies of teaching and learning in specific content. The way they construct their teaching in response to these factors is then evident in the particularities of their PCK.
CHAPTER OVERVIEW

The intention of this chapter was to highlight a number of issues that we consider important in shaping thinking about teaching. In each case, although the points may at first appear relatively simple, on further consideration, the impact of each issue creates questions about the nature of teaching and learning and the way in which they might be played out in practice. These issues include:

- Teaching is not telling.
- Learning how to teach is about much more than collecting a set of activities to use in the classroom.
- The ideal teacher understands how students learn and recognizes a number of factors that impinge on the quality of students’ learning; and, on the basis of that understanding, chooses and employs teaching procedures and approaches to promote learning.
- Teaching is problematic.
- Teachers who teach for understanding develop professional knowledge about teaching and improve their practice through reflecting on their practice and on the experiences and insights of other teachers. This commonly involves trying to think about teaching and learning from different perspectives in order to develop deeper understandings of teaching and learning situations.
- Teachers’ professional knowledge requires a special language in order to facilitate better expression and sharing of ideas about teaching and learning.
Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one’s subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that makes it comprehensible for others. Since there are no single most powerful forms of representation, the teacher must have at hand a veritable armamentarium of alternative forms of representation, some of which derive from research whereas others originate in the wisdom of practice. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners, because those learners are unlikely to appear before them as blank slates. (Shulman, 1986, pp. 9 - 10)

Pedagogical content knowledge (PCK) is an academic construct that represents an intriguing idea. It is an idea rooted in the belief that teaching requires considerably more than delivering subject content knowledge to students, and that student learning is considerably more than absorbing information for later accurate regurgitation. PCK is the knowledge that teachers develop over time, and through experience, about how to teach particular content in particular ways in order to lead to enhanced student understanding. However, PCK is not a single entity that is the same for all teachers of a given subject area; it is a particular expertise with individual idiosyncrasies and important differences that are influenced by (at least) the teaching context, content, and experience. It may be the same (or similar) for some teachers and different for others, but it is, nevertheless, a corner stone of teachers’ professional knowledge and expertise.

It stands to reason that in order to recognize and value the development of their own PCK, teachers need to have a rich conceptual understanding of the particular subject content that they teach. This rich conceptual understanding, combined with expertise in developing, using and adapting teaching procedures, strategies and approaches for use in particular classes, is purposefully linked to create the amalgam of knowledge of content and pedagogy that Shulman (1986, 1987) described as PCK.

Recognizing one’s own PCK is perhaps most evident when teaching outside an established area of subject expertise. No matter how capable a teacher might be when teaching his or her specialist subject, both skills and ability are immediately challenged (and typically found wanting) when teaching content with which there is little familiarity. When teaching outside one’s area of subject expertise, despite having a well developed knowledge of teaching procedures (e.g. Venn diagrams, concept maps, interpretive discussion, etc.) or strong specialist content knowledge (e.g. specialist of physics or biology or chemistry, etc.) a teacher’s skill of combining such knowledge of content and pedagogy in meaningful ways for particular reasons is no longer so readily apparent. Issues associated with difficult aspects of the topic, students’ alternative conceptions, important big ideas, conceptual hooks, triggers for learning and so on, are not well known or understood by the teacher when rich understandings of subject content is lacking, and it is in elements of professional practice such as these that PCK stands out as different and distinct from knowledge of pedagogy, or knowledge of content alone.

Because the development of teaching approaches that respond to a deep knowledge of the content is something that is built up and developed over time, it is possible that the knowledge of pedagogy and knowledge of content may blur, making recognition of PCK difficult. But, when teaching outside one’s area of subject expertise, the distinction may begin to stand out more readily because PCK cannot simply be “imported” from one subject area to another. Therefore, being able to see into science teachers’ practice in ways that goes beyond knowledge of teaching procedures and content and into the amalgam that is PCK is important, if the expertise of exemplary science teaching is to be highlighted and better valued.
particular content is better understood by students in a given context, because of the way the teaching has been organised, planned, analysed and presented. The following section develops this idea further as knowledge of pedagogy and content are unpacked and analysed in an attempt to illustrate how insights into the nature and development of PCK might be better recognized and understood.

**Venn diagrams**

A Venn diagram is a teaching procedure “borrowed” from mathematics (for detailed explanation, see White & Gunstone, 1992). It is a way of illustrating relationships between things (people, organisms, events, etc.) and, as such, is an excellent teaching procedure for probing students’ understanding of concepts, definitions and the relationships between members of different sub-sets of a universal set. Venn diagrams can be seen as a generic teaching procedure; however, when used in particular ways, at appropriate times, with particular subject matter content, PCK becomes apparent (as the following attempts to illustrate).

At one level, Venn diagrams as a teaching procedure can be applied as a generic approach to testing meaning of such things as definitions (see Figure 2.1 below). The simple Venn diagram in Figure 2.1 demonstrates the relationship between herbivores, carnivores, and omnivores in terms of the commonly stated definition of each. This Venn diagram (Figure 2.1) demonstrates that herbivores and carnivores have different characteristics from one another, and that a carnivore is not a herbivore, and vice versa. However, an organism that displays the features of both is classified as an omnivore (i.e. eats both meat and plants). Therefore, when teachers use Venn diagrams they may do so because, drawing on their knowledge of pedagogy, they recognize how helpful they are as a teaching procedure for bringing out salient features important to understanding particular aspects of specific content knowledge.

Moving beyond the teaching procedure alone though, when a teacher’s rich conceptual understanding of the subject content is the driving force behind the choice of the elements for students to use in drawing a Venn diagram, may well be indicative of PCK. As an important indicator of exemplary practice, PCK begins to emerge because the manner in which the content knowledge is being developed, questioned, manipulated, and tested is the driving force for the way the content and pedagogy are both shaped, and interact, in practice. Therefore, a teacher’s purposeful use of Venn diagrams for developing students’ understanding of differences between, and implications of, learning, in ways designed to develop richer conceptual understanding of the content beyond the basic facts, is strongly suggestive of the amalgam of content and pedagogy that is PCK.

Arguably, the type of reasoning underpinning the construction of practice (outlined above) is PCK if a teacher deliberately chooses Venn diagrams to explore terms and/or categories within a content area to challenge students’ understanding and is dramatically different from simply applying a teaching procedure because it “works”. In such a case, the teacher’s content knowledge is important in shaping not only what terms are selected, but also, and equally important, which terms are not used. Further to this, an understanding of some of the difficulties and points of confusion that students experience with the content may well be important in the selection of the terms, when to use Venn diagrams, and how to help students move beyond knowledge as facts, in order to pursue the development of understanding. Moving beyond the simple example illustrated in Figure 2.1, consider the Venn diagram in Figure 2.2.

In this case, a Biology teacher’s PCK may well be evident because the choice of these two terms (plants and animals) for students to use highlights a common difficulty inherent in the topic of classification. This seemingly straightforward Venn diagram takes on new significance when considered in conjunction with Figure 2.3 (what the teacher intends the students to construct).
In this case (Figure 2.3), the Biology teacher’s deep knowledge of the content makes the use of Venn diagrams much more valuable for learning that content than if it were applied simply as a generic teaching procedure. The use of these terms shows how the particular teaching procedure may be used with particular content at a particular time to begin to seriously develop students’ understanding; as opposed to simply defining the terms.

If a student made the shift in understanding highlighted in the change from Figure 2.2 to 2.3 then the teacher would gain important indications of student learning that offers valuable feedback to the teacher not only about the effectiveness of learning, but also about the effectiveness of the teaching. (Similarly, if Figure 2.3 were the first student response, the teacher would equally be well informed about the effectiveness of the learning and further implications for teaching). In addition to this, the use of Venn diagrams in this way also creates opportunities for exploring that which might populate the intersection of both sets in ways that create a real “need to know” for students and help to highlight important aspects of taxonomic classification, its use, and ways of applying it (beyond rote learning) so that richer conceptual understandings might be encouraged. Constructing teaching in this manner is indicative of PCK and is clearly distinct from “just” applying one’s knowledge of content and/or pedagogy generically.

Venn diagrams are not the only teaching procedures that offer such insights. There are many others that are equally important. For example, the use of concept maps further helps to elaborate this notion of PCK by demonstrating how the combination of content and pedagogy leads to understandings that are specific to expertise in a content field and certainly builds, in different ways, on aspects of the applicability, value, and purpose underlying the use and knowledge of practice inherent in Venn diagrams.

**Concept maps**

Concept maps were originally developed by Joseph Novak of Cornell University (see Novak, 1991; Novak & Gowin, 1984; Novak & Wandersee, 1991 for detailed descriptions and use through teaching and research). Concept maps are a powerful tool for organizing and representing knowledge and they emerged from his research into the development of children’s knowledge of science. Like many good teaching ideas, concept maps have been used, adapted and adjusted by teachers for a considerable period of time. Although concept maps were originally designed along the lines of hierarchical representations, the way they have been refined and adapted (see White and Gunstone (1992), in particular) illustrates how, just as with the case of Venn diagrams, their use as a generic teaching procedure is nowhere near as insightful in terms of knowledge of relationships between teaching and learning in a content field, as when applied for a specific pedagogic reason.

The use of concept maps offer other ways of seeing into PCK that also helps to illustrate how PCK extends beyond knowledge of content or pedagogy alone. The concepts used (whether teacher or student generated, and why) offer possibilities for examining the reasoning underpinning such practice. In addition, the links that explain the connections of, or relationships between, the concepts offer further insights. For example, these links may vary from being relatively superficial and few in number to detailed, complex and numerous. So the value of a concept map from a teacher’s perspective, beyond the understanding developed by students when constructing it (which is important in its own right), is the information that it conveys to a teacher about students’ learning and about the way in which the teacher’s teaching has influenced the process.

Exemplary practice, as evidenced through PCK, is highlighted, then, when concept maps are used by a teacher for a particular reason, with particular content, for a particular purpose, in contrast to being introduced to simply change the normal classroom routine. Consider, for example, the difference between the two student concept maps on the topic of plants shown in Figures 2.4 and 2.5. In considering these two concept maps, interesting questions surrounding the nature of a teacher’s PCK arise. On the one hand, in terms of content knowledge, there are questions about the concepts the teacher has selected for use and why they might be important in relation to the overall topic/theme to which they pertain, or whether or not the class or individual students generated their own concepts. On the other, in terms of knowledge of pedagogy, there are interesting questions about how the students may have been instructed to approach the task: whether they worked as individuals, in pairs or small groups; whether the concept mapping exercise was a one off activity or perhaps an introduction to the unit; something to be revisited
duals and/or after the unit had been completed; or products to be shared, discussed and redrafted as a consequence of learning with and from others.

As the differences between Figures 2.4 and 2.5 illustrate, the use of concept maps can bring into sharp focus such things as: relationships between teaching and learning; concept attainment; misunderstandings and difficulties; such that the thoughtful use and considered timing of the teaching procedure in concert with the concepts that form the basis of the concept map, can actually illustrate how the amalgam of a teacher’s knowledge of content and pedagogy that is PCK creates opportunities for valuable feedback on the essence of the teaching and learning experiences.

It is not difficult to see then how, through the use of this teaching procedure and the subsequent student responses, a science teacher might not only see into students’ learning but also gain insights into issues that may need further attention, revisiting or challenging. When all of the issues and questions outlined above are considered in light of the notion of PCK, it becomes increasingly clear that exemplary practice is more likely to be realised when the specialist knowledge that teachers develop, as a consequence of their careful and thoughtful approach to developing content knowledge understanding through the use of particular pedagogical approaches, is to the fore in their thinking and their actions.

By conceptualizing practice in ways that foster the interaction of knowledge of content and knowledge of pedagogy into the type of relationship indicative in PCK, teachers can surely be described as developing and displaying their specialist knowledge and skills of teaching. Importantly, the insights into PCK that might be evident in the use of concept maps in the way we have described here begins to bring to life some of the aspects of PCK noted by Shulman (1986) at the start of this chapter, i.e. ‘[that] the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners, because those learners are unlikely to appear before them as blank slates’ (p. 10). What the teacher’s use of concept maps does in this case is to naturally elicit students’ own views, preconceptions and misconceptions in ways that might not be so forthcoming through more “normal” classroom activities. Therefore, when this teaching procedure is used with this topic, it may well be because the teacher recognizes the importance of learners constructing and reconstructing their knowledge of particular concepts and their inter-relationships to better grasp a richer understanding of the topic as a whole.

![Figure 2.4: A student’s initial concept map on plants](image)

However, despite the insights into PCK that may be available by considering a science teacher’s use of particular teaching procedures in a particular situation for a particular reason(s), the use of teaching procedures alone does not, in itself, capture the essence of PCK.

As much of the research into PCK has demonstrated, it is a complex construct that, in many ways, is only fully recognized when seen through the cumulative effect of the way a teacher constructs and teaches a unit of work. Therefore, although considering a teacher’s use of such things as Venn diagrams, concept maps and other teaching procedures offers helpful insights into the nature of PCK, to isolate these as PCK alone may only lead to an over-simplification of the interaction of content and pedagogy that is embodied in that which is so often tacit in a teachers’ practice. And it is this tacit nature of aspects of the professional knowledge of teachers that so often overshadows the underlying knowledge and skills (for themselves and others); perhaps, as noted earlier, because development is gradual and occurs over extended periods of time.
When Shulman introduced PCK to the education community it was a construct that was particularly appealing to academics: ‘Yet, although PCK as a construct was seductive to researchers, few concrete examples of PCK emerged in subject areas’.

As noted in Chapter 1, Mandi Berry and Philippa Milroy were confronted by the difficulties of implementing constructivist approaches to teaching (in particular when working from students’ prior views and then attempting to address their alternative conceptions). They found, to their alarm, that the research literature was of little help to them in their daily attempts to change their teaching and to concurrently enhance their students’ learning of science.

Just as Mandi and Philippa found, so too a similar situation applies when considering the notion of PCK, i.e. that the manner in which research into PCK has been conducted has created an impasse for teachers. The research literature on PCK is certainly extensive; however, the outcomes of such research appear to speak more to educational researchers and other such academics than to teachers who surely are not only the producers of such knowledge, but also important end users.

Although PCK offers opportunities to explore interesting ideas about that which successful teachers know in order to teach in ways that achieve student understanding, the general “fuzziness” of the concept has meant that that which is searched for and uncovered is variable indeed. In fact, in some instances, the concept has been interpreted such that some examples of PCK appear to carry little resemblance to the construct as initially conceived by Shulman.

Until recently, much of the research on PCK tended to suggest that interest in the construct was not necessarily linked with finding ways of helping teachers (whether pre-service, beginning or experienced) to improve their practice. Rather, much time and energy was expended evaluating PCK as opposed to exploring concrete examples of how teachers teach particular content topics in particular ways that promote understanding. Therefore, unfortunately, PCK has not been developed through the research literature in ways that necessarily directly correlate with enhancing the practice of science teaching. Nor has PCK research been developed in ways that might encourage it to be widely used by teachers as a central aspect of their practice; a crucial issue in making the tacit explicit and therefore leading to a purposeful refining of one’s expertise i.e. professional learning.

This very point is highlighted by the work of Van Driel et al. who concluded that research on science teachers’ PCK should enable useful generalizations to be made. We would agree with this view. It seems reasonable to expect that there would be some similarities in teachers’ PCK if they had similar backgrounds in teaching and learning science and taught similar curriculum in similar contexts. In fact, the work of a number of researchers internationally lends support to this view whereby common big ideas for the topic Particle Theory (see Chapter 4 for a fully worked example) were apparent in studies in Australia and South America. This is not to suggest that all teachers’ PCK in a given subject area is, or should be the same, rather that some generalizable features may well apply that are informative to subject
specialists as they adopt, adapt and adjust this important feature of professional knowledge to suit their own practice in their own context.

Despite these few instances of generalizability noted above, literature of teachers’ PCK based on specific topics that might be informative and applicable in the work of science teachers is largely lacking. Reasons for the sparse offerings may be related to the approach of researchers in this area.

By and large, researchers have tended to compare and contrast particular aspects of PCK of individual teachers and of groups of teachers, use case studies of novice and/or practising teachers to explore aspects of their topic specific PCK, and to explore the affect on science teachers’ PCK of programs that relied on the researchers’ own PCK in that particular content area. Hence, building up strong portrayals of what PCK in particular content areas might look like and how it might be enacted in practice has not been a common research agenda.

Given the potential value to teachers of some form of generalization about PCK, it is somewhat disappointing that research efforts have not yet provided detailed overviews of successful teachers’ PCK so that some overarching and meaningful synthesis might be available for others to consider. One interesting exception though is the work of Van Driel et al. who offered descriptions of what teachers do to help students understand the dynamic nature of chemical equilibrium. At the heart of this concern about the research into PCK and its applicability in the work of teachers is, of course, teachers themselves.

It is an unfortunate aspect of teachers’ working lives that their professional knowledge is neither overtly recognized by teachers themselves nor by others (e.g. bureaucrats, policy makers, other observers of educational processes). This is a matter of a concern, for despite the fact that knowledge, and practice, of teaching is fundamentally based on deep conceptual understandings of both content and pedagogy (which is then played out in concert with the demands of the teaching and learning context), it is not common for the majority of teachers to talk, or think about, the specialist knowledge and skills they have and continually develop (and that is encapsulated in PCK). Yet, as Shulman (1987) explains, PCK is ‘the category [of teacher knowledge] most likely to distinguish the understanding of the content specialist from that of the pedagogue’ (p. 8) and as such is a vital element of teachers’ professional learning; something that should be recognized, developed, and valued in education generally.

PEDAGOGICAL CONTENT KNOWLEDGE: BEYOND JARGON

An issue associated with the notion of PCK that needs to be acknowledged and addressed is associated with problems carried by the stereo-typical view that some teachers tend to see academic constructs such as PCK as ‘just another piece of jargon’. However, to dismiss PCK in this way is to adopt a pejorative view and is counter to some of the most recent research that has illustrated the value of using the construct purposefully.

A real and serious issue in teaching is the ability to capture, portray and share knowledge of practice in ways that are articulable and meaningful to others. Typically, teachers share their knowledge through stories, anecdotes and other forms that offer brief glimpses into their expertise and skill in the classroom. What is not always so readily apparent in this form of sharing is that teachers are in fact producers, not just users, of sophisticated knowledge of teaching and learning. And, the complex ideas associated with exemplary practice are better able to be portrayed and shared in meaningful ways if labels and descriptors such as PCK are better understood and used. Therefore, a language that comprises aspects of professional practice is central to moving knowledge of practice out from the individual and into the professional community at large. For example, in many studies by teacher researchers, language (a shared vocabulary) has been central to the development and sharing of their sophisticated knowledge of practice.

A crucial aspect of a shared language then is its ability to capture ideas and practices in ways that embrace the development of knowledge and skills and leads to a greater valuing of teachers’ professional knowledge – of which PCK is an important element. It seems reasonable to suggest that a shared vocabulary (a language of teaching and learning that conveys meaning and understanding of practice), is important in teaching so that ideas, knowledge, procedures and practice can be conveyed in ways that move beyond conceptions of good teaching as the simple accrual of activities, despite the fact that teachers constantly need things that will “work in class tomorrow”. It is perhaps this tension between activities that work and the underlying principles of practice, or generalizable features from specific teaching and learning situations, that masks the importance of a shared vocabulary and has been an inadvertent barrier to its development and valuing in the profession.

Mitchell, when reviewing the accumulated stories, anecdotes and portrayals of practice that PEEK teachers had published over more than 15 years, drew attention to the underlying features of PEEK teachers’ knowledge as described in his Principles of Teaching for Quality Learning. What he did in articulating these Principles was to highlight that PEEK teachers had developed and gradually refined a language that facilitated the sharing of their professional knowledge in meaningful ways about: the manner in which they spoke about their students’ learning behaviours; the creation and development of
teaching procedures designed to enhance metacognition; and their learning through researching their own practice. When he considered this accumulated body of wisdom from a big picture perspective, some common features were evident to him which, when described as Principles of Teaching for Quality Learning were significant to PEEL teachers because of the meaning inherent in, and commonly understood, by that group of teachers.

When considering the complexity of PCK, a similar need is apparent for a language of practice associated with the ability to describe, portray and articulate pedagogical content knowledge so that others might be able to see how to develop and apply it in their own teaching and learning contexts. It seems obvious that the pedagogical reasoning underpinning particular ways of teaching particular content needs to be shared within the profession. Without a language to discuss this specialist knowledge of teaching, the deep and rich skills and knowledge of practice that teachers carry will not be so readily acknowledged, shared or valued.

Just as terms such as linking, metacognition and sharing intellectual control are part of the language of teaching and learning for PEEL teachers, so too important features of PCK need to be recognized, described and articulated so that PCK can be developed and shared beyond the individual. However, a cautionary note in all of this is that the use of a special language of teaching and learning may not always be well understood by others and therefore be criticized as jargon. Yet, jargon serves a very useful purpose for those familiar with the language because it carries meaning beyond the words alone; it is shorthand for more expansive and complex ideas. Therefore, although jargon may be interpreted by some as alienating or overly theoretical, it is an important basis on which the specialist skills, knowledge and practice of teaching can be shared, developed and manipulated to not only improve practice but also, to ultimately enhance students’ learning.

When viewed this way, PCK and any associated language of practice that underpins it could be described as “jargon that matters”. It matters for the development and understanding of teachers’ professional knowledge and practice. Importantly, such jargon would be “built up from practice” and could therefore be considered as theoretically based in, and applicable to, the work of teachers. We would argue that PCK needs to be underpinned by a language developed for articulating this specialist knowledge of teaching and learning that enhances the dissemination of this rich knowledge of content specific teaching so that it is applicable to, and meaningful in, the work of teachers more generally.

The following chapter begins to explore approaches to portraying PCK and in so doing begins to develop and use a language that, we hope, helps to capture the essence of such knowledge so that it carries real meaning for others and, in so doing, moves beyond pejorative views of jargon. For example, some of the terms we introduce include:

- Big Ideas
- Frameworks
- Teacher Thinking
- Alternative conceptions
- Narrative accounts
- Representations of practice
- Teaching procedures
- Constructivism
- Ascertaining understanding
- Linking
- CoRe (Content Representation)
- PaP-eRs (Pedagogical and Professional-experience Repertoires).

In some cases, these terms carry specific meaning to particular aspects of PCK not previously developed or described. In others, language has been “borrowed” from other fields in order to import that meaning into our approach to capturing, portraying and articulating PCK so that that which is understood in one field of teacher knowledge might also be equally applicable in this field. One example is that of alternative conceptions/misconceptions, where the work of many science education researchers has been important in shaping the knowledge of student learning in science inherent in those apparently simple terms. Another example is that of constructivism which carries understandings of learning that teachers would no doubt readily identify with even if they do not necessarily use that term in their everyday conversations about practice. Clearly though, the point is that language matters and carries particular meaning and portraying (sometimes simply) very complex ideas and practices: developing a common language of PCK is then important.

The use and development of the language that occurs in Chapter 3 is designed to capture the essence of the ideas, prompts and questions about practice that we trust helps to share knowledge of exemplary practice. In so doing, we suggest that PCK as a construct can then be better understood and be more useful and applicable in science teachers’ professional learning.
CHAPTER 2

CHAPTER OVERVIEW

The intention of this chapter was to highlight a number of issues that we consider important in coming to understand the nature of Pedagogical Content Knowledge. These issues include the ideas that:

- Pedagogical Content Knowledge (PCK) is a notion invented by academics to describe an aspect of the professional knowledge and expertise developed by teachers.
- PCK refers to the knowledge that teachers develop about how to teach particular content/subject matter in ways that lead to enhanced student understanding of that content.
- PCK is not the same for all teachers within a given content area despite the fact that there are many commonly shared elements of teachers’ PCK within that content area.
- Understanding teachers’ practice in terms of PCK may be helpful in making explicit and refining teachers’ professional learning about practice.
CHAPTER THREE

PORTRAYING PCK

[On the one hand, while] novice teachers and experienced teachers who have not taught a particular topic before may have little or no PCK in that specific content area. On the other hand, “successful” teachers in a given content area, by which we mean those whose teaching in that particular content area promotes student learning, are likely to have well-developed PCK in that specific content area. Thus the question arises as to whether it is possible to enhance teachers’ topic specific PCK in those content areas where their PCK is under-developed using, in some way, successful teachers’ PCK and so “prevent every teacher from reinventing the wheel” (Van Driel, et al., 1998, p. 677). This question encapsulates one of the ultimate purposes for our research … to represent this teacher knowledge using a format which may be useful in pre-service and in-service science teacher education. (Mulhall, Berry, & Loughran, 2003, p. 1)

As alluded to in previous chapters, we believe that successful teachers have a special knowledge that informs their teaching of particular content and that special knowledge is encapsulated in PCK. We have also highlighted that few concrete examples of PCK exist in the literature. As a consequence, it is difficult for science teachers to access PCK in ways that might be meaningful for their practice. Therefore, the very notion of PCK remains somewhat elusive, and as suggested in Chapter 2, a shared language is needed to access and support the ideas foundational to PCK so that the concept (and underlying knowledge) might be better understood and valued.

If PCK as a construct is to be meaningful in science teachers’ work, we would argue that it is important for concrete examples of PCK to be articulated and documented so that teachers can access and use them in shaping their own practice. However, as much of our research has highlighted, explaining what PCK is, or might look like, and then actually uncovering, describing, articulating and portraying it, is another matter all together.

Over an extended period of time, we have attempted to develop concrete examples of PCK in ways that we hope might be helpful to teachers, teacher educators and students of teaching so that PCK might be more than just another academic construct. How that work has progressed is explained in detail in the remainder of this chapter and, we trust, establishes sufficient understanding of our conceptualization of PCK for the reader to make the following chapters (which are based around examples of subject specific PCK), accessible and useable.

SHAPING FACTORS IN CAPTURING AND REPRESENTING PCK

The manner in which we have come to develop our approach to capturing and representing PCK is based on the view that it is important to recognize and acknowledge that there are many successful and effective ways for teaching particular science content. Teacher thinking about teaching is complex, and it is important to promote ways of sharing teachers’ professional knowledge of teaching to further enhance understanding of teaching and learning in science.

Teaching and learning in science

Over the last 20 years, there has been much research into students’ alternative conceptions/ misconceptions about science ideas (see, for example, Pfundt & Duit, 1994). This research generally draws on personal and social constructivist ideas, i.e. that students’ learning is influenced by their own personal cognitive frameworks which they have developed as a consequence of their prior experiences and by the ideas of the culture in which they live (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Clearly then, from this perspective, effective or successful science teaching places the teacher in the role of mediator of learning, as opposed to being a transmitter of knowledge (Tobin, Tippins, & Gallard, 1994). Thus, effective science teaching is more likely if the teacher is not only knowledgeable about common student alternative conceptions/misconceptions, but draws on this knowledge to shape teaching. In so doing, successful teachers monitor students’ understanding in ways that allow them to be responsive to students’ learning and create opportunities that help them to more fully grasp the concept(s) under consideration. Obviously, this cannot be achieved by simply telling students what they should think and why. Finding ways of influencing the understandings that they construct and challenging students’ alternative conceptions is at the heart of such teaching. Therefore, as opposed to telling, it is crucial that teachers create meaningful and engaging activities, practices and discussion between students and/or between teacher and student(s) about science ideas and the ways these differ from everyday understandings (Driver, et al., 1994; Hollon, Roth, & Anderson, 1991; Leach & Scott, 1999; Tobin, et al.,
1994). However, as many teachers readily acknowledge, such teaching creates a tension because although
they might value such an approach, they also know that it takes longer to move through the prescribed
curriculum than would be the case if using more “traditional” teaching approaches. The dilemma, then, is
that although students’ conceptual understanding may well be richer, the amount of content covered is
likely (at least, initially) to be much less than that which might normally be achieved (Hollon, et al., 1991,
p. 149).

In the development of our work in PCK, we have drawn on this constructivist perspective so that one
aspect of PCK which we have paid particular attention to has been related to the nature of teachers’
knowledge that helps them to develop and apply teaching approaches that promote student learning in
ways other than “teaching as telling”, i.e. seeking to better capture and “unpack” constructivist
approaches to teaching.

Teacher thinking

The research literature has long recognized that teaching is a complex activity. Good teaching is not the
implementation of a number of standard steps or protocols that can be passed from one teacher to another
in some technical form (Clarke & Peterson, 1986). Teacher thinking has been highlighted as important for
seeing into the complex nature of teaching by uncovering the sophisticated thinking that informs teachers’
actions and decision making in particular teaching situations (Husu, 1995). Therefore, how, when and
why teachers think about what they do becomes an important aspect of making the tacit explicit in
attempting to capture and portray PCK.

From our perspective, whether or not a particular action by a teacher is illustrative of that teacher’s
PCK is dependent on the thinking upon which the teacher reasons through and develops the subsequent
teaching action (or in some cases, apparent inaction, e.g. in using extended wait-times). Therefore, our
representations of topic specific PCK have been developed to make explicit the nature of successful
teachers’ pedagogical reasoning and the associated decision making within the context of the teaching of
that particular science content. In so doing, we believe that it provides evidence of teachers’ use of
pedagogical content knowledge (whether they explicitly describe it that way themselves or not: a teacher
may have PCK without necessarily labelling it in that way).

Talking about teaching through stories

Connolly and Clandinin (2000) have highlighted the importance of teachers’ stories and, in so doing, have
illustrated that sharing experience through narrative is one way of accessing teachers’ knowledge about
practice. Teachers seem naturally drawn to discussing teaching by drawing on stories of their experiences
because they include the rich detail that accompanies the context so crucial to understanding not only
what has happened, but also how and why. In many ways, teachers’ stories actually carry most of the
important information that helps other teachers to identify with, and therefore extract their own meaning
from, a given description of a teaching and learning situation.

Through narrative we begin to understand the actor’s reasons for the action, and are thereby
couraged to make sense of these actions through the eyes of the actor. This understanding
constitutes an enormous contribution to learning about and getting better at teaching.
(Fenstermacher, 1997, p. 123)

Conle (2003) suggested that the use of narrative is helpful for viewing, and interpreting situations, from
different perspectives, and in different ways. Through narrative there is a greater possibility that the story
of the writer might influence the knowledge of the reader in ways that cause aspects of the tacit to become
more explicit, thus resulting in personal and professional changes in the reader, and to their ‘visions of
what can be’ (p. 11). And that is at the heart of why teachers’ stories are often so powerful, not only for
the story-teller but perhaps more importantly, for the reader/listener.

One aspect of our representation of teachers’ PCK is built around the importance of story primarily
because narrative constructions can often best represent the holistic nature of a given teaching and
learning experience and the knowledge of the teacher working in that situation. Good stories capture and
portray aspects of the context, teachers’ and students’ experiences, their plans and actions, and their views
and responses in ways that can carry more meaning than if such things are simply stated as “variables in a
research project”.

A FRAMEWORK FOR REPRESENTING CONCRETE EXAMPLES OF PCK

In order to represent and share what we believe to be science teachers’ PCK about particular content
areas, we have, as a result of ongoing conversations, workshops and observations over a number of years,
developed a format that captures important aspects of successful science teachers’ knowledge of science
subject matter knowledge and pedagogy. This particular PCK format is made up of two elements. The first element is what we have called a CoRe (Content Representation; pronounced ‘core’) which offers an overview of the particular content taught when teaching a topic. The second element is what we have called PaP-eRs (Pedagogical and Professional–experience Repertoires; pronounced ‘papers’), which are succinct, but specific, accounts of practice that are intended to offer windows into aspects of the CoRe.

PCK representations demonstrated through a CoRe (or in some cases CoRes; see, for example, Chapter 5: Chemical Reactions; Chapter 7: Force; and, Chapter 9: Genetics) and the associated PaP-eRs combine to create a Resource Folio of PCK on that given content/topic. Such Resource Folios (see the examples that comprise Chapters 4 – 9) have been constructed by using the prompts associated with a CoRe as discussion points when working with teachers to gather the data that eventually becomes the completed CoRe and associated PaP-eRs (for a full description, see Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Loughran, et al., 2004).

The Resource Folios that are offered in the following chapters are a synthesis of our research data from both individual and group interviews with experienced, successful science teachers and from observations of their science teaching. These representations of PCK are not meant to represent a single teacher’s PCK, but rather the most common and agreed upon aspects from a particular group of science teachers at a particular time. Therefore, although many aspects of the CoRe and PaP-eRs may be common to other teachers, it is not intended that these Resource Folios are the only or best PCK of that subject/topic. Rather they are illustrative of PCK for that topic more generally, so they are not “the PCK for that topic” but concrete examples of PCK within that topic.

CoRe: CONTENT REPRESENTATION

A CoRe (Content Representation) provides an overview of how a given group of teachers (those we worked with in this project) conceptualize the content of particular subject matter or topic. A CoRe is developed by asking teachers to think about what they consider to be the “big ideas” associated with teaching a given topic for a particular grade level(s) based on their experience of teaching that topic. These big ideas are discussed and refined and then, when generally agreed upon, become the horizontal axis of a CoRe (see Figure 3.1 the blank template for an example). The big ideas are then probed and quizzed in different ways through the prompts that are listed on the left hand vertical axis of the CoRe (see Figure 3.1), so that specific information about the big ideas that impact on the manner in which the content is taught can be made explicit.

Through this process, the CoRe becomes a generalisable form of the participant teachers’ pedagogical content knowledge as it links the how, why, and what of the content to be taught with what they agree to be important in shaping students’ learning and teachers’ teaching. In the next section, we develop this further by explaining each aspect of the CoRe.

Big science ideas/concepts

The horizontal axis of a CoRe contains the “Big Ideas” which refers to the science ideas that the teacher(s) see as crucial for students to develop their understanding of the topic. In some cases a big science teaching idea may be the same as a big science idea but the two are not necessarily synonymous, as the interaction between content and teaching impacts how teachers conceptualize these big science teaching ideas. There is no defined number of big ideas, but typically, in a given topic, we have found that teachers generally settle on between 5 – 8 big ideas. Too few big ideas suggests that too much may be encompassed in a single big idea whilst too many big ideas suggests the topic may be being “broken down” into “chunks” of information that appear unconnected. Therefore, developing the big ideas can be quite a time consuming task and requires considerable thought and debate.

What you intend the students to learn about this idea

This is the first prompt in the vertical axis of a CoRe and is a starting point for “unpacking” the big ideas. Our research suggests that experienced teachers have little difficulty in being specific about what a particular group of students should be able to learn. However, in contrast, teachers inexperienced in a given topic tend to be unsure what the students are capable of achieving. Therefore, as a beginning point in unpacking science teachers’ understanding of what matters in a particular content area and why, this prompt is very helpful.

Why it is important for students to know this

In the multitude of competing curricular decisions that teachers face, deciding what to teach must be linked to why it is important to be taught. We suggest that successful teachers draw on their experience
CHAPTER 3

and knowledge of the given subject matter with that which they know to be relevant to students’ everyday lives, so that they can create meaningful ways of encouraging students to grasp the essence of the ideas/concepts at hand. Often, though, the reason why it is important for students to know about these ideas/concepts is linked to other curricular aims.

What else you might know about this idea (that you don’t intend students to know yet)

Teachers often make difficult decisions about that which needs to be included, and that which needs to be excluded, in order for students to begin to develop an understanding of the topic/theme. Although successful science teachers recognize the value in not oversimplifying content, or maintaining its complexity in order to enhance understanding, they also balance this with a knowledge that perceived difficulty and/or unnecessary confusion might detract from students’ learning. This then influences their thinking in relation to the next prompt in a CoRe.

Difficulties/limitations connected with teaching this idea

As Shulman (1986) and many others have noted, teachers come to develop and respond to insights they gain about potential difficulties, when teaching a particular topic. In science, this is particularly borne out in the research into alternative conceptions/misconceptions, and the limitations of such things as models and analogies in promoting understanding or explaining phenomena. Expert science teachers use this knowledge and information to shape the manner in which they teach particular concepts and topics. Without this feature of PCK it could well be argued that teaching is not genuinely responsive to constructivist views of learning and is therefore not concerned with students processing, structuring, synthesizing and reconstructing their knowledge, but more so with adding new “chunks” of learning onto existing knowledge regardless of their existing views/understanding of the content.

Knowledge about students’ thinking which influences your teaching of this idea

As an aspect of the CoRe, this prompt is important for helping to make explicit that which teachers have come to know through their experience of teaching the given topic, and how that knowledge influences their thinking about their teaching. Successful science teachers plan their teaching around that which they have learnt about students’ commonly held ideas about the topic (which may not be the same as, but also include, understandings of alternative conceptions as mentioned earlier) and the manner in which students “usually respond” to the topic (including level of interest) and specific teaching and learning situations developed through the topic.

Other factors that influence your teaching of this idea

This prompt in the CoRe is aimed at unpacking teachers’ contextual knowledge about students as well as their general pedagogical knowledge in order to explore how these might influence the manner in which they approach and construct their teaching.

Teaching procedures (and particular reasons for using these to engage with this idea)

Just as Chapter 2 raised the importance of a shared vocabulary in talking about teaching, so too the expression ‘teaching procedures’ is important in differentiating between different aspects of planning for, and the teaching of, subject matter. Mitchell and Mitchell (2005) distinguished between teaching activities, procedures, and strategies. They suggested that a teacher may well use an activity to introduce students to a topic and as such, the activity can be applied to a situation “as is”. Teaching procedures, they suggest, are tactical in that teachers choose which procedures to use, when, how, and why in order to promote different aspects of learning. On the other hand, a strategy incorporates an overall approach such as ‘building a classroom environment that supports risk-taking” or “sharing intellectual control’ (see Principles of Teaching for Quality Learning (Mitchell & Mitchell, 1997) briefly outlined in Chapter 2).

Generally then, familiarity with a range of teaching procedures is an important aspect of PCK because ‘expertise in choosing teaching procedures that are appropriate to the intended learning outcomes and knowing not only how to use them, but why, under what changed circumstances, and being able to adjust and adapt them to meet the contextual needs of the time’ (Loughran, 2006, p. 49) is an indication of sophisticated expertise. Clearly, teaching procedures alone cannot guarantee learning, but informed and thoughtful use in appropriate ways at appropriate times can influence student thinking and may well promote better understanding of science ideas (Leach & Scott, 1999).
Specific ways of ascertaining students’ understanding or confusion around this idea

Teachers constantly monitor students’ understanding and progress (both formally and informally). This prompt is designed to explore how teachers approach this aspect of their teaching in the topic in order to gather different perspectives on the effectiveness of their teaching as well as adjustments to their thinking about the same, or similar, situations in the future.

Overview of the CoRe

When creating or working with a CoRe, it is important to recognize that some sections may contain more detail than others. It is not intended that a CoRe should have a prescribed amount of information or ideas. It contains only the amount of information and ideas proposed by those involved in its formation and, in some cases, some of the boxes may well be left empty. However, because of the form of representation that a CoRe takes, it allows for changes and/or additions to be made as further insights are gained, or as issues are further clarified and refined. Obviously then, there is not one CoRe for each topic. Different groups of teachers may develop different CoRes for the same topic, as other things, not least being experience and contextual factors, inevitably influence teachers’ understandings of, and actions in, practice.

The CoRe enables a solid base around which an overview of teachers’ PCK for a topic can be articulated, and provides insights into the decisions that teachers make when teaching a particular topic, including the linkages between the content, students, and teachers’ practice.

A CoRe, despite containing valuable information and possibilities for understanding PCK, is of itself not PCK because the information represented in a CoRe tends to be propositional in nature, and is thus limited in terms of providing insight into teachers’ experiences of practice. For this reason we developed PaP-eRs (Pedagogical and Professional-experience Repertoires), which, for all intents and purposes, are windows into PCK that bring to life science teachers’ practice, thinking and understanding of teaching particular content in particular ways at particular times.

PaP-eRs: PEDAGOGICAL AND PROFESSIONAL-EXPERIENCE REPERTOIRES

A PaP-eR is a narrative account of a teacher’s PCK that highlights a particular piece, or aspect, of science content to be taught. (In some cases, PaP-eRs can be constructions that draw on more than one teacher’s PCK even though it may be represented as an individual’s PCK.) A PaP-eR is designed to purposefully unpack a teacher’s thinking about a particular aspect of PCK in that given content, and so is largely based around classroom practice. PaP-eRs are intended to represent the teacher’s reasoning; that is, the thinking and actions of a successful science teacher in teaching specific aspects of science content.

As narrative accounts, PaP-eRs are meant to ‘elaborate and give insight into the interacting elements of the teacher’s PCK in ways that are meaningful and accessible to the reader, and that may serve to foster reflection in the reader about the PCK under consideration, and to open the teacher reader to possibilities for change in his/her own practice’ (Mulhall, et al., 2003, p. 9).

The “voice” of a PaP-eR varies depending on that which is being portrayed. For example, some PaP-eRs are drawn from a student’s perspective, others from that of the teacher, some take the form of an interview, others a classroom observation or the thinking inherent in a teacher reflecting on the problematic nature of a given concept, while others highlight particular curriculum issues or concerns. As a consequence, the format of a PaP-eR is responsive to the type of situation it is attempting to portray. Some use call-out boxes to elaborate on particular points or to draw attention to specific instances that might otherwise be easily overlooked.

A PaP-eR is generally introduced to the reader using an overview that is in a different ‘voice’ to that of the PaP-eR itself. This overview is designed to offer the reader quick and easy access to the ideas and approaches that are elaborated within the PaP-eR.

Overall, a PaP-eR is one of many in a Resource Folio for teaching about a particular science topic, each designed to link to one or more specific aspect(s) of the CoRe in the relevant content area, but each focusing on different aspects of successful teachers’ PCK. Together in a Resource Folio, PaP-eRs bring the CoRe to life and offer one way of capturing the holistic nature and complexity of PCK in ways that are not possible in the CoRe alone. A number of PaP-eRs focus on how teachers come to see teaching and learning situations with new eyes as they ‘reframe’ (Schön, 1983) their practice in response to new insights gained from questioning the taken-for-granted in the teaching and learning of particular science concepts. We suggest then, that in so doing, the total package of a Resource Folio (specifically those examples that are Chapters 4 – 9) gives the reader access to the process of development of teachers’ pedagogical content knowledge in that particular science topic.
Figure 3.1 is a blank CoRe or template that demonstrates the major components that comprise this particular aspect of a Resource Folio including: (a) the Important Science Concepts/Ideas, i.e. the big ideas for teaching that particular topic; and, (b) the prompts for unpacking the big ideas, e.g. what you intend the students to learn about this idea, etc.

As the template illustrates, the variety of ideas and information developed in a CoRe covers a range of important aspects of the teaching and learning of specific content/concepts. Even though this template is spread over a double page, as will quickly become evident in the following chapters, it is not possible to neatly confine a CoRe to such an orderly space. However, for the purposes of constructing a CoRe, the layout demonstrated is helpful in terms of managing a visual representation of that which is involved in developing and working with a CoRe.

In our work with science teachers, we have consistently found that using a blank CoRe on a double sheet, such as that in Figure 3.1 is significant for helping participants to negotiate different regions of the CoRe and to move freely from one area to another as their ideas and thoughts progress.

With each group of teachers, a different pattern emerges for responding to the big ideas and associated prompts. In some instances, teachers prefer to work through one big idea, moving from the prompt at the top of the page down to the final prompt at the bottom of the page. Others work across the pages following an individual prompt across each big idea, one at a time. Not surprisingly, others randomly move across the whole CoRe, initially responding to those spaces that most capture their attention and then working their way back to those areas that require more time and energy. However, the last two prompts tend to draw out the richest detail as they tap into teachers’ stories of their classroom practice and encourage the sharing of narratives. It is from these instances that ideas for PaP-eRs are usually first able to be encouraged and also become a catalyst for further PaP-eRs across different fields of the CoRe.

As explained earlier, there is no set amount of information or given number of big ideas that must be completed in order to “finish a CoRe”. Working on a CoRe creates a sense of professional learning and sharing of the expertise of teaching that, for many teachers, is considerably different from what they have previously experienced. In discussing, debating, and articulating the aspects of the different spaces that eventually become a given CoRe, science teachers quickly develop ways of discussing their practice that make that which is normally implicit, private, and individual, explicit, clear and meaningful for themselves and their colleagues; some of these approaches have been important in shaping the language we have used in representing our conceptualization of PCK. For example, the very notion of “big ideas” and the nature and wording of the prompts appear to make sense to teachers and have been created by working closely with them. As a result, we have found that through this language, teachers do not become embroiled in some of the more common arguments that revolve around questions such as: ‘what content has to be in this topic?’ Rather they reflect on the importance of the concepts that are crucial to understanding the topic, as opposed to stating the propositional knowledge alone.

The template in Figure 3.1 is a good starting point for re-examining the way in which particular topics are taught and for refocusing attention on the skills, knowledge and expertise that is so often overlooked in the normal routine of teaching.

OVERVIEW OF CoRe AND PaP-eRs

A Resource Folio of a given content area contains a CoRe(s) and the associated PaP-eRs which together create complementary representations of successful teachers’ PCK about teaching particular subject matter, to a particular group of students in a particular way for very important pedagogical reasons. A CoRe is a holistic overview of teachers’ pedagogical content knowledge related to the teaching of a given topic, and the associated PaP-eRs are narrative accounts designed to purposefully offer insights into specific instances of that PCK. A Resource Folio is therefore a collection of two specific interactive elements that together represent that which is PCK, as developed and articulated by a given group of science teachers that, in some cases, have constructed joint understandings (more common in the CoRe), and in others, individual illustrations of specific practice (more common in PaP-eRs). It therefore seems reasonable to suggest that Resource Folios are generalisable (while still being complex and quite specific) instances of teachers’ pedagogical content knowledge about teaching particular science content and offer other science teachers new and valuable ways of accessing that aspect of the knowledge base of teaching.

There is little doubt that much of that which comprises teacher knowledge is implicit. Teachers are rarely afforded the opportunity to reflect on their practice in a formalised or sanctioned manner, i.e., it is not part of their allocated teaching duties. More than this, curriculum documents usually represent topic specific teaching as “blocks of content” to “be delivered” by teachers to students in the hope that learning might occur. Sometimes, activities and teaching procedures might be suggested but such advice is not usually strategic and “engagement in learning” is often a misnomer for “fun”. It is little wonder that in the busy work of teaching, as Appleton (2002) observed, discussion about subject specific teaching and learning is so frequently limited to what works; and even more so to what will work in my class next lesson?
An immediate feature of the structure of a CoRe is the manner in which it encourages teachers to problematise the content and teaching. The overall impact of a Resource Folio is that it provokes thinking about what is important in the teaching of a topic and why, and, even more so, how teachers view their existing practice in conjunction with possibilities for future development.

In many ways, the combination of CoRe(s) and PaP-eRs in a Resource Folio is an invitation to teachers to begin to reflect on and identify that which they need to know and to think further about when teaching a new topic (e.g. ‘What are the big ideas for teaching this topic to this particular group of students?’; ‘What should I expect students to learn?’; ‘Why?’; ‘What teaching procedures will help this group of students to understand a particular big idea?’; and so on). Further to this, they help to bring to the front of one’s thinking the value of a construct such as PCK that, when made explicit, illustrates the value of focusing on the special skills, knowledge, and ability that successful subject specialists (in this case, science teachers) possess and continue to develop. Therefore, CoRes and PaP-eRs not only represent teachers’ topic specific PCK, but also act as triggers to encourage other teachers (both pre-, and in-service teachers, as well as science teacher educators) to begin to embrace the notion of PCK in their own practice.

CHAPTER OVERVIEW

There has long been a simplistic distinction made between teaching as the swampy lowlands of practice (Schön, 1983) and the ivory tower of academia that is the world of theory. As a consequence, the theory-practice gap is often cited as a reason for the lack of influence of theory on practice, and even more so, of practice on theory. However, some have spent considerable time and energy trying to link both in more meaningful ways. There is the recognition that ‘teachers need help to think more complexly about their practice and the reasons behind their actions in the light of how particular pupils learn and in relationship to specific formal academic knowledge’ (Bullough, 2001, p. 665), as well as the realisation that experienced teachers see into, and respond appropriately to practice because they are: ‘able to make a deeper interpretation of events, [as they] interpret significant contextual clues’ (Calderhead, 1996, p. 717).

We suggest that what Resource Folios (as encapsulated by both CoRe and PaP-eRs) offer teachers (pre-service, beginning and experienced, as well as science teacher educators) is a powerful, accessible and useful representation of PCK that is responsive to practice and in practice is important to a theory of teaching. This chapter has attempted to bring these often two different worlds together by explaining our conceptualization of PCK based on the following important aspect of teaching and learning in science.

- Our representation of teachers’ PCK draws on constructivist perspectives of teaching and learning.
- Teachers’ PCK becomes evident through making explicit the nature of their pedagogical reasoning, and the associated decision making within the context of teaching particular science content.
- Our representations of teachers’ PCK use a format that is comprised of 2 elements:
  1. a content representation (CoRe) – which offers a holistic overview of particular science concepts related to a content area; and,
  2. accounts of teachers’ practice (PaP-eRs) – which illustrate specific aspects of the content within the complexity of a science teaching/learning experience.

Together CoRes and PaP-eRs combine to create a Resource Folio of PCK for a given topic/content area, that are illustrative of PCK for that science topic.

A Resource Folio is an example of PCK for a given science topic but it is not the only, or necessarily the most correct way of representing PCK within that subject/topic: it is an example of PCK.

A Resource Folio (particularly the CoRe) is not intended as a curriculum document/syllabus although it may well shape the way curriculum/syllabus is conceptualized.
<table>
<thead>
<tr>
<th>Year Level for which this CoRe is designed.</th>
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<tbody>
<tr>
<td>What you intend the students to learn about this idea.</td>
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<tr>
<td>Why it is important for students to know this.</td>
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<tr>
<td>What else you know about this idea (that you do not intend students to know yet).</td>
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<tr>
<td>Difficulties/limitations connected with teaching this idea.</td>
</tr>
<tr>
<td>Knowledge about students’ thinking which influences your teaching of this idea.</td>
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<tr>
<td>Other factors that influence your teaching of this idea.</td>
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<tr>
<td>Teaching procedures (and particular reasons for using these to engage with this idea).</td>
</tr>
<tr>
<td>Specific ways of ascertaining students’ understanding or confusion around this idea (include likely range of responses).</td>
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</tbody>
</table>

**Figure 3.1: CoRe template**
<table>
<thead>
<tr>
<th>IDEAS/CONCEPTS</th>
<th>BIG IDEA ‘C’</th>
<th>BIG IDEA ‘D’</th>
<th>BIG IDEA ‘E’</th>
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*Figure 3.1: CoRe template (continued)*