A frame for the development of preservice science teachers

Deborah CORRIGAN

Centre for Science, Maths and Technology Education
Faculty of Education
Monash University
AUSTRALIA

E-mail: Corrigan@Education.monash.edu.au

Received 3 Apr., 2007
Revised 12 Jun., 2007

Contents

Abstract

This paper describes how a frame has been used to articulate the intentions of a preservice chemistry education course to students of that course. The frame, which draws on appropriate knowledge bases for teachers of science, is also used through the teaching of the course as a diagnostic and development tool to assist the learning of these preservice teachers. However, the success of using such a frame also relies on the use of reflective tools to monitor student learning, such as learning logs and portfolios. The paper also presents evaluations from students on the success of using this frame in this preservice chemistry teacher education course.

Introduction

Providing a frame for the development of preservice science teachers is not a new idea. However this paper describes how a frame has been used to articulate the intentions of a preservice secondary chemistry education course to students of that course, as well as ways this frame is used through the teaching of the course as a diagnostic and development tool to assist the learning of these preservice teachers.

The frame used in this course assumes that knowledge, skills and attitudes are all important aspects in the growth of preservice science teachers. This paper focuses on the knowledge domain as the development of skills and attitudes has been detailed elsewhere (Corrigan, 2005). The use of learning logs and portfolios as reflective tools is highlighted as they have been critical elements in the application of this frame within the course. The paper concludes with some final implications for preservice science teacher development.

Knowledge Domains for Teaching Science

Certain key ideas appear to be necessary for the development of preservice teachers regardless of the structure of the program in which they participate. As suggested by Gess-Newsome (1999) these include the integration of knowledge bases, informed decision-making, exposure to examples of teaching excellence and multiple and supported experiences. Teaching practice and university courses are widely accepted as important ways of supporting and modelling excellent teaching. However, there has been more variation in the research on the interpretation of how teachers integrate knowledge bases and make decisions. Some of the important knowledge bases for teaching science and how these can assist in the development of preservice science teachers are discussed below. The knowledge base for science teachers will be different from that of, for example, history teachers, as Shulman (1999) suggests:

> …teaching, like research, is domain-specific. This implied that teaching as “the transformation of understanding” rested on depth, quality and flexibility of content knowledge and on the capacity to generate powerful representations and reflections on that knowledge. (pxi)

A number of different schemes have been proposed for articulating appropriate knowledge bases for science preservice teachers. For example, Tamir (1989) proposed six knowledge bases: subject matter, pedagogy, subject matter specific pedagogy, general liberal education, personal performance and foundations of teaching. From a different perspective, Koballa, Graber, Coleman & Kemp (1999) in an investigation of prospective chemistry teachers’ conception of the knowledge base for teaching chemistry at the German *Gymnasium* proposed a nested structure for participants' conceptions where the different layers may be viewed as differing levels of personal experience. In this model, Koballa et al. suggest that preservice chemistry teachers perceive school chemistry knowledge and university chemistry knowledge as nested within multi-dimensional knowledge, which is itself nested within learner-orientation multi-dimensional knowledge. They hypothesise that:

> The participants' conceptions may represent different levels of personal experience that individuals accumulate when learning to teach chemistry. For example, it seems likely that prospective teachers experience university chemistry as important for chemistry teaching before considering knowledge of students or curriculum knowledge. (p283)

Personal experience becomes an important dimension here as the way preservice chemistry teachers have experienced their chemistry knowledge at school and university influences the knowledge they use for teaching.

In 1987 Shulman proposed seven domains of teacher knowledge which have contributed much to researching how knowledge bases are integrated by teachers and how they make decisions. The domains are content knowledge, pedagogical knowledge, knowledge of educational contexts, knowledge of learners, curriculum knowledge, pedagogical content knowledge, and knowledge of educational ends, purposes and values.

There are obvious similarities between the knowledge bases provided in all these models, particularly Tamir's and Shulman's, despite their different perspectives. (Tamir and Shulman look at these knowledge bases from the view of the (science) teacher educator rather than from the perspective of Koballa et al., which takes the perspective of the preservice chemistry/science teacher). All three highlight the importance of knowledge of subject, while Tamir's and Shulman's models both additionally identify knowledge of pedagogy, and subject specific pedagogy. Koballa et al.'s model highlights the importance of personal experience, but this may not count as category of knowledge, but rather a factor that influences knowledge. Importantly, all these models support the notion that successful science teachers require knowledge beyond the level of subject matter alone.

While Shulman's and Tamir's models clearly identify both pedagogical knowledge and subject specific pedagogy, or as Shulman terms it, pedagogical content knowledge (PCK), as important domains of knowledge, Morine-Dershimer and Kent (1999), in a discussion about the source of teachers' pedagogical knowledge and PCK, present facets of pedagogical knowledge that are essential to its development and also the relationship between Shulman's seven knowledge domains. This is reproduced in a modified version in Figure 1 where Morine-Dershimer and Kent's (1999) notions of facets of pedagogical knowledge and PCK have been combined into a single figure. The arrow linking these two diagrams (shown as a much thicker arrow) has been provided by the author, and while clearly providing a linkage between these two models, it also serves to emphasise the complex nature of these models. While Morine-Dershimer and Kent propose that context specific pedagogical knowledge is a precursor to pedagogical knowledge, this does not mean that pedagogical knowledge will be developed, and so the arrow representation is quite complex. For example, classroom management, instructional models and strategies and classroom communication and discourse all need to pay attention to educational goalsand assessment and evaluation as well as learners as important aspects of pedagogical practice.

Morine-Dershimer and Kent (1999) suggest that it is the development of "context specific pedagogical knowledge that helps to guide teachers' decisions and actions" (1999, p23) and provide the contextual basis for preservice science teachers' consideration of educational goals and evaluation and knowledge of learners, which are important precursors in the development of pedagogical knowledge. For science teachers, considerations of these domains (pedagogical knowledge, educational goals, purposes, values and evaluation and knowledge of learners and learning) are also critical aspects in the development of PCK.

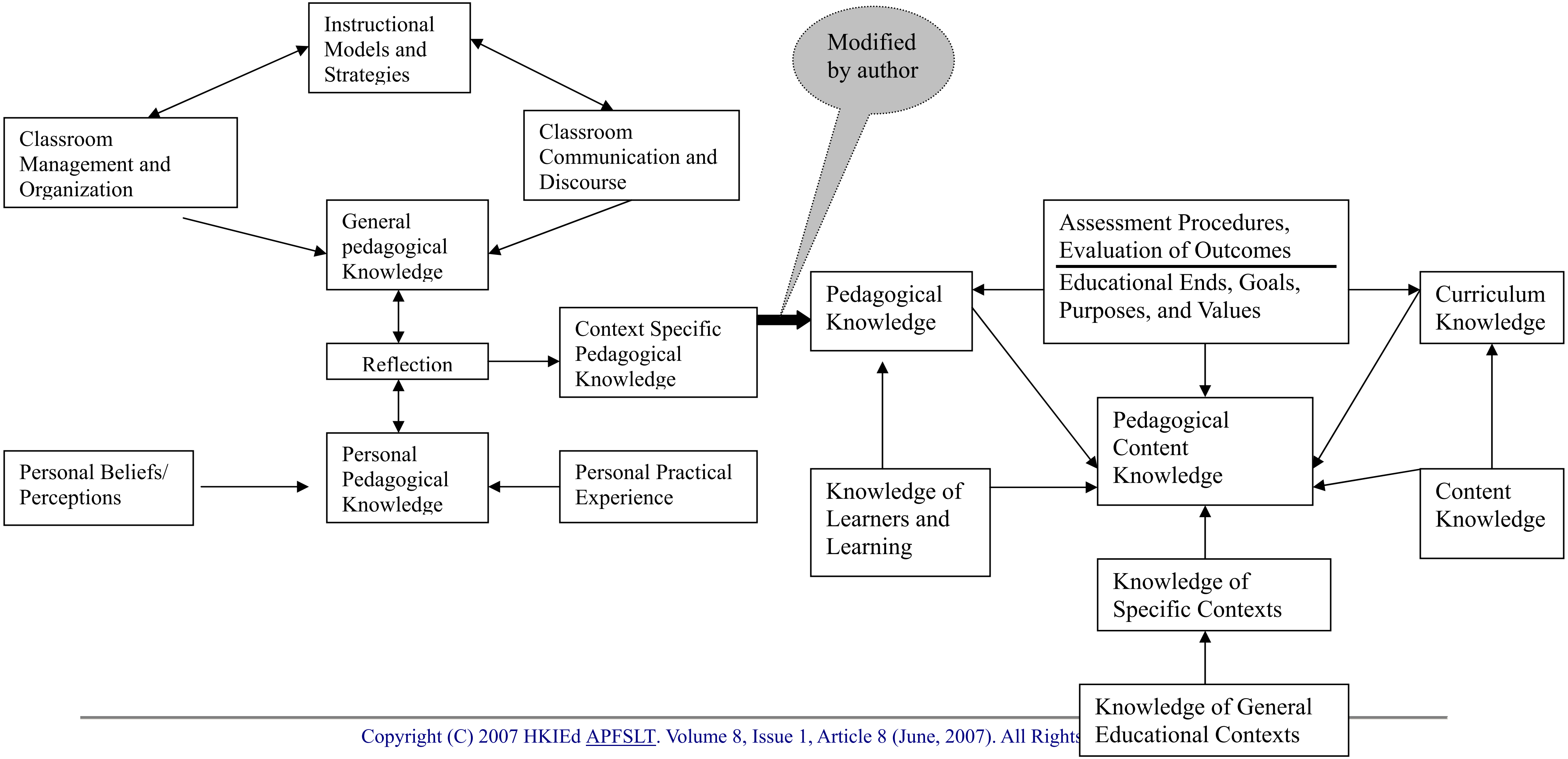
As Morine-Deshimer and Kent(1999) note there are three important points to note in this model:

- knowledge of educational ends and purposes is inseparable from knowledge about evaluation and assessment procedures;
- curriculum knowledge is fed by both content knowledge and knowledge of goals/assessment procedures, while pedagogical knowledge is fed by both knowledge of learners and learning and knowledge of goals/assessment procedures; and
- only the category of general educational contexts is further delineated to the sub-category of knowledge of specific contexts, but each of the other categories contributing to pedagogical content knowledge can be so delineated eg knowledge of specific content, specific curriculum, specific goals/assessment procedures, specific pedagogy, and specific learners (p24).

Figure 1: Modified version of 2 models proposed by Morine-Dershimer & Kent, 1999.

Figure 1: Facets of pedagogical knowledge
(Morine-Dershimer & Kent, 1999:p23)

Figure 2: Categories contributing to Pedagogical Content Knowledge
(Morine-Dershimer & Kent, 1999:p22)



Understanding the Facets of Pedagogical Knowledge and Pedagogical Content Knowledge

On first inspection it would be easy to view the facets of the pedagogical knowledge model as hierarchical with classroom management and organisation, instructional models and strategies and classroom communication and discourse being conceived as the development of technical aspects demonstrated by behaviour in the classroom. The model could also be viewed as a progressive continuum or a staged development in that it is necessary to acquire mastery of these three facets before a preservice teacher can “move on” in Furlong and Maynard’s terms. Furlong and Maynard (1995) support the notion of a staged development with pre-service teachers progressing from ‘personal survival’, to ‘dealing with difficulties’, to achieving confidence and competence in management and organisation, to eventually ‘moving on’ to pupil engagement. In this sense these facets can be viewed as being about practical competence. When pre-service teachers have not mastered these facets in their classrooms, they can often be judged to be weaker. In Furlong and Maynard’s stages of development, these preservice teachers are often operating at the lower stages (Stages 1-3; early idealism to personal survival to dealing with difficulties) as opposed to the higher stages of hitting a plateau (Stage 4, where preservice teachers look like teachers but lack understanding of teaching and learning) and moving on (Stage 5, where preservice teachers re-evaluate, plan and reflect in terms of pupil learning).

Personal pedagogical knowledge, personal beliefs/perceptions and personal practical experience could be interpreted as being of higher order in terms of the students’ understanding of their own teaching; the development of a higher order cognitive dimension in teaching. Preservice teachers need to develop and integrate all of the facets in their pedagogical knowledge model in order to make progress.

Classroom management and organisation, instructional models and strategies, and classroom communication and discourse have a significant cognitive dimension because as preservice teachers reflect on their personal beliefs/perceptions and personal practical experience and develop their personal pedagogical knowledge, they need to reframe these other three facets (classroom management and organisation, instructional models and strategies and classroom communication and discourse) in generating general pedagogical knowledge. Reflecting on their understanding of classroom management and organisation, instructional models and strategies and classroom communication and discourse in developing general pedagogical knowledge influences their personal pedagogical knowledge. This feeds back into an increase in their teaching repertoire, developing their context specific pedagogical knowledge. There needs to be feedback loops between all of the facets, and reflection becomes the critical facet in this process of facilitating these feedback mechanisms. It therefore becomes a critical component of any preservice science teacher education course to build in the use of reflective tools in order to monitor and evaluate preservice science teacher's development, as well as encouraging preservice teachers to self-monitor their own learning.

Similarly, the development of pedagogical content knowledge requires an integrated view, where all the different categories feed into the development of such knowledge. It could be viewed that the two aspects of the refined model represented in Figure 1, where the facet of pedagogical knowledge are represented on the left-hand side and the categories of knowledge that assist in the development of PCK are located on the right-hand side, help to distinguish between teachers' views of the "dailiness of teaching" as portrayed through the development of pedagogical knowledge and the more highly desirable professional development and "big picture" thinking portrayed through the development of PCK. For teachers, operating across all levels, but with increasing emphasis on the categories of knowledge located on the right-hand side of this figure would be desirable.

Others have also attempted to delineate the nature of PCK. Magnusson, Krajcik and Borko, (1999) proposed that PCK was composed of five components: orientation towards science teaching, knowledge of the curriculum, knowledge of science assessment, knowledge of science learners, and knowledge of instructional strategies.

Again the similarities can be seen with both the components proposed by Magnusson et al. and the categories and facets proposed by Morine-Dershimer and Kent (1999). Both highlight the importance of knowledge of assessment, learners, curriculum and instructional strategies. Magnusson et al.'s "orientation towards science teaching" differs slightly from Morine-Dershimer and Kent's model in that it is about teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level. Such knowledge and beliefs service as a conceptual road map that guides the instructional decisions a teacher makes about issues such as learning objectives, content of assignments, evaluation of student learning and the use of curriculum materials. This orientation towards teaching science does share some of the characteristics of what Morine-Dershimer and Kent have called knowledge of specific contexts.

In introducing preservice teachers to the complexity of learning how to be effective science teachers, there are a great many discrete entities of which the preservice teacher needs to be aware. Preservice chemistry teachers, a small subset of the larger science preservice teacher group, at Monash University, Australia, undergo a program that has been framed around the models represented above. As Gess-Newsome (1999) suggests

> Good models, like good theories, organize knowledge in new ways, integrate previously disparate findings, suggest explanations, stimulate research and reveal new relationships (p3).

The intention is that by making these ideas and intentions within a preservice science teacher education course explicit to the preservice teachers, they will take greater responsibility for their learning and development within these knowledge bases.

Chemistry Education – An example of a preservice science teacher development course

The chemistry education course for preservice chemistry teachers at Monash University, Australia, explicitly maps the intention of each aspect of the course using Shulman's seven knowledge domains and in addition makes clear what skills and attitudes are intended to be developed throughout the course of study. In addition, preservice teachers are asked to track their own learning and experiences through the use of learning logs (Kortagen, 1993) and the development of chemistry teaching portfolios (Loughran & Corrigan, 1995) as well as demonstrate their learning through assignments and practical performances, and evaluate their own learning, skill development and clarification of attitudes and values as well as the explicit intentions of the program.

Mapping of knowledge domains in the intended curriculum

As stated above, the intended curriculum is mapped against Shulman's seven knowledge domains. The mapped intentions of the course are communicated to preservice chemistry teachers in a variety of ways, predominantly in the course guide, as well as the mechanisms that are employed to track their learning.

From this initial mapping of curriculum, articulation of intentions and tracking of learning, it became clear that there were areas that needed further development. Table I below summarises the mapping exercise and indicates the frequency of the intended development of each of Shulmans' seven knowledge domains throughout the course. The heading used in this table are based on Shulamn's seven knowledge domains and the frequency refers to the number of times when these knowledge domains were the purposeful intent of the teaching. This frequency table is based on the coursework component of the course and does not attempt to map the school experience component. It should be noted here that while there is also clear intentions and mapping of skills, attitudes and values developed throughout the course, these will not be detailed here but have been detailed elsewhere (Corrigan, 2005).

Table I: Frequency for the intended development of each of Shulman's 7 knowledge domains with the Chemistry Education course.

	Content knowledge	**Pedagogical knowledge**	**Knowledge of educational contexts**	**Knowledge of learners**	**Curriculum knowledge**	**Pedagogical content knowledge**	**Knowledge of educational ends, purposes & values**
Frequency of occurrence throughout the course	22	26	7	19	17	16	18

From Table I is it clear that while some domains are well represented, particularly pedagogical knowledge and content knowledge, others are not. The low frequency score for knowledge of educational contexts is not such a surprise here as clearly the intention of the school experience within the course is designed to address this knowledge domain specifically. While the mapping exercise relates to the coursework component only, the link between the coursework and the school experience will only become apparent through student reflections and this may indicate a weakness in this study. The link between theory and practice appears limited at this stage.

Preservice chemistry teachers are asked to evaluate their own learning and the course intentions. This is done in a variety of ways such as through a learning log, development of a chemistry teaching portfolio as well as through a semi-structured 2-hour evaluation workshop held at the conclusion of the course. The responses from one cohort of students (n=20) are presented below.

Preservice chemistry teachers responses

The preservice teachers were asked at the end of their course:

> *Given the parameters under which this course has been constructed as outlined in the "Studying this unit" section of the unit guide, how successful has the unit been in developing the following knowledge domains in your opinion (course evaluation document).*

Their response are summarised in Table II where 1=strongly agree, 2 = agree, 3 = don't know, 4 = disagree and 5 = strongly disagree. N/R represents no response.

Prior to their completion of the course evaluation, a review session where the aim was to develop a shared meaning of what was meant by each of the seven knowledge domains listed was conducted. This was to planned to reduce some of the ambiguity that might arise from the use of these terms. The lecturer's explanation of these terms was also included in the "Studying the Unit" section of the Unit Guide that all students received at the commencement of the course.

The development of subject matter knowledge is not perceived as being developed by 40% of preservice teachers with an additional 15% unsure. However, there are 45% of students who do believe that subject matter is developed to some extent (20% strongly agree that it is developed) within the course.

These perceptions are interesting as all preservice chemistry teachers entering this course have at least a two year university sequence of study in chemistry, so their background subject matter knowledge is considerable. Many have indeed more than this with some Chemistry PhD and Masters degrees as part of their chemistry backgrounds.

Table II: Preservice chemistry teachers' responses to their perceptions of the success of the course in developing different knowledge domains (N=20).

Knowledge Domains	1	2	3	4	5	N/R
Subject matter knowledge	5	4	3	8		
Pedagogical knowledge	6	13	1			
Knowledge of educational contexts	4	4	7	5		
Knowledge of learners	6	9	4			1
Curriculum knowledge	7	8	3	2		
Pedagogical content knowledge	7	10	1	1		1
Knowledge of educational ends, purposes and values	11	8	1			

Given this background it is assumed (by the author as the lecturer) that much of the preservice chemistry teachers' subject matter knowledge is developed as part of their own school and university courses. This assumption may need some further consideration. There is some further development of subject matter knowledge as content areas such as acid/base chemistry, stoichiometry, atomic theory, the concept of substance and chemical reactions are some of the content areas used as contexts and on-going themes for developing understanding of teaching strategies.

In addition, specific attention is given to exploring the nature of science and the values inherent within science and science education. However, preservice chemistry teachers do not perceive an exploration of the nature of science as part of their subject matter knowledge. Their definition of this domain relates specifically to knowing chemistry content.

Koballa et al (1999) in their study of preservice chemistry teachers found that there were four major conceptions prevalent amongst the group they studied. The first conception was university chemistry knowledge. Some preservice teachers believed that knowledge of the discipline of chemistry taught at university provided the most important prerequisite for effective chemistry teaching. This type of knowledge as garnered from the preservice teachers collective responses in interviews was of three types: chemistry facts and concepts; chemical theories, and laboratory and problems solving skills. Koballa et al make the suggestion that:

> … the notion of knowledge of chemistry as the only essential for secondary teaching has associated with it the belief that good chemistry teaching is directly related to one's understanding of chemistry content as presented at university (p277).

From my own experience with preservice chemistry teachers, this is often the perception at the beginning of the course, particularly from those preservice chemistry teachers with higher degree chemistry qualifications and some experience of tutoring in university. However, the responses from the preservice chemistry teachers above indicate that the assumption that preservice chemistry teachers have significant chemistry knowledge on entry and its relevance to teaching needs to be explored further. It may be that at the end of the chemistry education course, the students' perception of what is appropriate chemistry knowledge has changed throughout the year.

Analysis of the data presented in Tables 1 and 2 indicate some agreement across other knowledge domains. Preservice chemistry teachers appear to agree that the course has successfully begun the development their pedagogical knowledge, PCK and knowledge of educational ends, purposes and values. There is some uncertainty for some students in terms of the successful development of knowledge of learners and curriculum knowledge.

Knowledge of educational contexts, which preservice chemistry teachers have defined as knowing how schools function day-to-day, the philosophy of the school, its facilities and approaches to teaching, reflects again the lack of emphasis in this knowledge domain of the coursework component of the course, with some 35% of students uncertain and 25% disagreeing about the development of this knowledge domain in this course. On the other hand some 40% of preservice chemistry teachers either strongly agreed or agreed that this knowledge domain was successfully developed. These responses to the development of knowledge of educational contexts continue to highlight the gap between linking theory and practice.

Responses from preservice chemistry teachers' learning logs however, indicate that the link between theory and practice might be better than at first anticipated. From these learning logs, it has become clear that some preservice chemistry teachers, who according to Furlong and Maynard's model would be in the Stages 4 or 5 – moving on to student engagement, are indeed linking their theory and practice.

> *I started to see the "light" about concept maps. Until now I just could not see how I was going to use them in teaching… I had lots of reservation. What is a good concept map? How to evaluate a concept map? …After the tutorial I was convinced that it can be used and I am going to try to use it. The practical application in my classroom helped me to understand, plus the ideas[on] how to evaluate them. I was very satisfied as this discovery made my day. It crystallized in me that concept maps will be part of my teaching repertoire and evaluation of students' understanding. I will have to plan in advance and polish my ideas of how to introduce concept maps to students if they do not already know them. (Harry – learning log)*

While Harry's comment is just an example of many similar comments from preservice chemistry teachers, it was clear that the students making such comments were generally beyond Furlong & Maynard's Stage 3 "dealing with difficulties" of their preservice teacher development, while those who were at Stages 1-3 did not make these links as often, if at all. When preservice teachers are focuses on student engagement and have 'mastered' many of the technical components of teacher, they are able to reflect on what they have learnt and relate it to what they are teaching, such as in the above example using concept maps.

From the preservice chemistry teachers' data it has become evident that they have found it incredibly helpful to have the intentions of the course explicitly articulated. In knowing the intention and purpose for the course, the preservice chemistry teachers have felt they have more control over their experiences and learning. The use of learning logs has been an invaluable tool for promoting preservice chemistry teachers' responsibility for their own learning, gaining insights into and monitoring their learning as they interact with course materials, each other, schools and experienced teachers.

> *Initially I found the readings and the content really challenging. But after a bit of help – it was really interesting. It was good to focus on a particular content area –*

> *substances- and follow that through the initial part of the course with some very practical examples. [In t]he five weeks of teaching practice I really saw evidence of my teacher and then myself in linking the theory I had experienced with the practice in the classroom. I saw practical examples of the theory – the links were there! I'm glad I had the opportunity to look at the micro level before I had to look at the curriculum stuff- the big picture stuff. I didn't know teaching was so complex. But it has given me the courage to raise the level of science in my class[more] than what I saw and experienced on the teaching rounds. (Evan (a pseudonym) - learning log)*

Preservice chemistry teachers commented that they found the concept of PCK difficult, but after examining experienced teachers' examples of PCK, combined with the school experience, they began to recognise the benefits in developing this type of knowledge as shown below by this artefact from one student's (Ross- a pseudonym) chemistry teaching portfolio.

Artefact 2: *Excerpt taken from my Meta reflection regarding my PCK*

'The concept of pedagogical content knowledge fascinates me. I had always thought of teaching as getting up in front and my words would just flow and the students would learn! ………… I feel that my PCK is very immature at the moment. I say this because I think I am still in the process of learning what is really involved in the transformation of my CK [content knowledge] into PCK.'

'I am aware that my CK plays a big part in this transformation and I am still learning other aspects of pedagogy that will assist me in a knowledgeable transformation.'

(Ross, 2005)

Rationale:

When I wrote this reflection I was uncertain as to the reasoning and necessity of pedagogical content knowledge (PCK). Upon further reading and reflection on this I realised that I was subconsciously making a serious assumption about teaching and learning. I had assumed that there was one type of teaching and one type of learning.

This line of thought obviously simplifies the concepts of and transformation of CK and PCK, but in reality this is not the case. There are many different teaching styles and learning styles which make the transformation of my CK into PCK crucial in teaching efficiently and effectively.

I now visualise PCK as being the medium that bridges the gap between my knowledge of chemistry and efficient and effective teaching and learning of chemistry. The greater the depth of knowledge I have of the chemistry content the greater the potential to develop and implement different teaching and learning strategies for all my students. (Ross – chemistry teaching portfolio)

The development of a chemistry teacher portfolio, with myself as their chemistry education lecturer as an informed reader, has also been beneficial in the development of themselves as chemistry teachers:

> *The development of a portfolio of pieces of work, resources and other articles relating to teaching has enhanced my understanding of my own learning and development. Being able to easily view previous efforts and contrast these with newer items is a great aid to reflection, and offers encouragement through the obvious progress that has been achieved. The subjective nature of the collection of portfolio items results in a very individual and personalized piece. (Richard – learning log)*
>
> *My chemistry portfolio was a piece that contributed to the developing of my own role as a person and as a teacher (my inner core and outer concentric rings). Before the portfolio, I had some confusion in my own mind about what I represented as a chemistry teacher and a person. I knew that the inner core was 'me' - All that I have become from all that I have experienced. The outer, the medium, between me, society, and the students was hazy and fragile in its structure. The portfolio allowed me to realise that my professional knowledge, professional experience and professional evaluation form concentric rings around my 'me' core. It is through these concentric rings that I see the strategies of teaching & learning. It is through these concentric rings that my focus on students and the outside world will be forever visualised. And as time goes by and I develop my own teaching experiences these concentric rings will become firm structures that will eventually*

> *wrap tightly around the inner 'me' core – new concentric rings will present themselves but all I have experienced as a teacher and a person will become part of me, part of my learning and always part of my reflections. (Fred- learning log)*

Such a portfolio is different from those normally constructed for example for employment purposes. The informed readership is a critical factor in these portfolios as the students know me as their lecturer and I know them and their abilities from both their coursework and professional experiences. These portfolios are about students articulating all the ideas they have about what it means to them to be a chemistry teacher, and what is important, and requires them to put some cohesive structure into this thinking. They have become important tools for helping students reflect on what they have learnt and what they believe about chemistry teaching and requires them to articulate these ideas. The importance of reflecting on and articulating your ideas is an important part of the process in developing chemistry teachers.

Some implications

The intention throughout the chemistry education course at Monash University is to develop the best quality beginning chemistry teachers possible. In order to do this, a number of models have been used to help make it explicit to students (as well as myself) what are important knowledge, skills and attitudes that need to be developed in science teachers. While this paper deals with the knowledge domain, the development of skills and attitudes is equally important and has been detailed elsewhere (Corrigan, 2005).

What has been fundamental in this education process is the modeling of practice for the students. The articulation of what are the intentions of the course, the reflection and responsiveness to students' reflections on their own learning, and the use of structured evaluation processes that have been clearly articulated to students, have been crucial elements in generating an environment where students are expected to be responsible for and articulate their own learning. The reflective tools have also been particularly important in capturing some evidence of the links preservice teachers see between theory and practice.

The models used in this course have helped student development as they can be used as diagnostic tools to know where students may be and also as developmental tools in aiding future development. However, the success of using such models rest on the reflective tools that are used to monitor student learning. While this course has used learning logs and portfolios as the major reflective tools, there are many more possibilities.

Teaching is a complex activity and learning to teach is even more so. While there are a number of possible models that can be used for the development of science teachers, their use can be enhanced through good modeling, clear articulation of intentions and reflection on the learning that takes place.

References

Corrigan, D.J. (2005). Preparing teachers of chemistry for a global market in Rodrigues, S. (Ed). *International Models of Teacher Professional Development*, Nova Science Publishers, Huappauge, New York.

Corrigan, D.J. & Fensham, P.J. (2002). The Role of Chemistry in Vocational Education in Gilbert, J. (Ed.), *Chemical Education: Towards research-based practice*. Dordrecht: Kluwer publishing

DeVos, Boult and Pilot. (2002). Chemistry Education Curriculum in Gilbert, J.K., DeJong, O., Justi, R., Treagust, D. & VanDriel, J. (Eds.), *Chemical Education: Towards Research-Based Practice*, Kluwer, Dordrecht.

Furlong, J and Maynard, T. (1995). *Mentoring Student Teachers: The Growth of Professional Knowledge* Routledge

Gess- Newsome, J. (1999). Forward in J. Gess-Newsome & N.Lederman (Eds) *Examining Pedagogical Content Knowledge*, Dordrecht, Kluwer Publishing.

Koballa, T., Graber, W., Coleman, D., Kemp, A. (1999). Prospective teachers' conceptions of the knowledge base for teaching chemistry at the German Gymnasium. *Journal of Science Teacher Education, 10*(4), p269-86.

Kortagen, F.A.J. (1993). Two modes of reflection. *Teaching and Teacher Education*, *9*(3), 317-326.

Magnusson, S., Krajcik, J. and Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching in J. Gess-Newsome & N.Lederman (Eds) *Examining Pedagogical Content Knowledge*, Dordrecht, Kluwer Publishing

Morine-Dershimer, G. and Kent, T. (1999). 'The Complex Nature and Sources of Teachers' Pedagogical Knowledge' in *Examining Pedagogical Content Knowledge*, Dordrecht: Kluwer Academic Publishers.

Loughran, J.J. & Corrigan, D.J. (1995). Teaching portfolios: a strategy for developing quality learning in pre-service science teachers. *Teaching and Teacher Education, 11*(6), 565-577.

Shulman, L. (1987). Knowledge and teaching: Foundation of new reform. *Harvard Educational Review, 15*(2), 4-14.

Shulman, L. (1999). Introduction as cited in J. Gess-Newsome & N.Lederman (Eds) *Examining Pedagogical Content Knowledge*, Dordrecht, Kluwer Publishing, pxi.

Tamir, P. (1989). Subject matter and related pedagogical knowledge in teacher education. Paper presented at the *annual meeting of the American Educational Research Association*, Washington, DC.