Journal of Science and Mathematics
Education in Southeast Asia
2009, Vol. 32 No. 1, 18-35

The Development of Thai Pre-service Chemistry Teachers' Pedagogical Content Knowledge: From a Methods Course to Field Experience

Chatree Faikhamta
Department of Education, Faculty of Education, Kasetsart University, Bangkok, Thailand

Richard K. Coll
Centre for Science and Technology Education Research University of Waikato, Hamilton, New Zealand

Vantipa Roadrangka
Department of Education, Faculty of Education, Kasetsart University, Bangkok, Thailand

This study investigated the journey of four Thai pre-service chemistry teachers as they sought to develop their Pedagogical Content Knowledge (PCK) throughout a PCK-based chemistry methods course and field experience. In an interpretive case study approach we drew upon classroom observations, semi-structured interviews, chemistry content knowledge surveys, beliefs surveys and documents as data sources. Data analysis was inductive involving categorical aggregation, followed by a search for correspondence and patterns. The findings indicate that at the beginning of the PCK-based chemistry methods course, the pre-service chemistry teachers had a limited background and restricted educational foundation experiences. Through the methods course, they developed their PCK and broadened their views about the nature of science, and learner-centred views of teaching and learning. During their field experiences, they were able to incorporate their methods course learning into their lesson planning appropriately but they faced some difficulties in enacting their PCK in teaching.

Key words: PCK; Thailand; Science; Pre-service teacher; Constructivism; Chemistry

Introduction

In these early years of the twenty-first century, pedagogical content knowledge (PCK) has been described as the hallmark of knowledge base for teaching particular subjects (Geddis, Onslow & Beynon, 1993). The notion of PCK was first proposed by Shulman (1986), and his work forms the knowledge base for research on PCK. PCK represents an important tool to define what it means to be a good teacher (Magnusson, Krajcik, & Borko, 1999), and it is reflected in teachers' understanding of what concepts are difficult for students to learn, the selection of appropriate instructional materials, and pedagogies such as the use of metaphor and analogy to help students make sense of the learning experiences (Bucat, 2004; Zembal-Saul, Blumenfeld, & Krajcik, 2000). The notion here is that familiarity with general pedagogies is not enough for teaching a particular topic. Rather, pedagogy needs to be blended with content (Shulman, 1986). Hence, if teachers hold insufficient PCK, they may provide inappropriate concept demonstrations, which may in turn reinforce student misunderstandings or encourage rote learning (Geddis et al., 1993).

In the context of Thai science teacher education, although the term PCK is not used or well-known, it is implicitly embedded in a variety of educational documents which form the national framework for education (e.g., the *1999 National Education Act* - Office of the National Education Commission, 1999, and the *Thai Science Teachers Standards* - Institute of Promotion of Science & Technology Teaching [IPST], 2002). In the *Thai Science Teachers Standards*, Thai science teachers must acquire science content knowledge, understand the nature of science, have knowledge of different pedagogies, and use this knowledge appropriately in the teaching of particular content. Thai teachers are also expected to implement constructivist-based teaching strategies and integrate such strategies with their PCK. However, recent research suggests that pre-service and in-service teachers in Thailand are not familiar with constructivist-based teaching and learning perspectives and activities, and have difficulty in integrating their PCK knowledge base (Pillay, 2002). Faikhamta and Roadrangka (2005) investigated problems of Thai pre-service science teachers during their professional experience training. They suggested that pre-service science teachers had problems in designing learning activities to fit the science content and student abilities, creating instructional materials suitable for the science content, and using questioning techniques to elicit students' prior

knowledge. They also argued that the science teacher programme emphasised *general pedagogical knowledge* rather than *content-specific pedagogy* – PCK.

Therefore, it is proposed that it is necessary to develop a science education preparation programme to enhance Thai pre-service teachers' PCK. In response to the demands for capable Thai science teachers, a challenging aspect of the present work was to design a chemistry methods course based on the notion of PCK, and to investigate how chemistry pre-service teachers develop and transfer their PCK into teaching practice during the methods course and their field experience. The research questions for this work are:

1. How does a PCK-based chemistry methods course influence the development of PCK for Thai pre-service chemistry teachers?
2. How do Thai pre-service chemistry teachers develop their PCK during their field experienced?

Theoretical Framework

The research presented in this work was set within the conceptualisation of PCK and based on social constructivist views of teaching and learning, in which learning is seen as a social process occurring in particular educational contexts. A significant implication of constructivist-based views of learning (Tobin, Tippins & Gallard, 1994) for science teacher education is the notion of a pre-service science teacher as a 'learner'. A pre-service science teacher is a person who actively constructs their views of teaching and learning science, and brings to the science teacher education programme prior knowledge and beliefs (Bell & Gilbert, 1994). From a social-constructivist perspective, within a particular social context, pre-service teachers construct or reconstruct their own knowledge and beliefs through support and guidance from knowledgeable persons (Cobern, 1993; Watson, 2006), collaboratively working with other people (Bell & Gilbert, 1994), and reflecting on their own and other's ideas (Abell & Bryan, 1997; Capobianco, 2007). These strategies provide ways to facilitate pre-service teachers' knowledge of how to teach a particular topic to particular students.

Pedagogical Content Knowledge for Teaching Chemistry

With attention given to teachers' knowledge, PCK has become a central focus in learning how to teach particular subjects. PCK was first proposed by Shulman (1986), and his work forms the knowledge base for research on PCK. Shulman argues that PCK requires teachers to blend their subject

content knowledge, pedagogical knowledge related to a subject, knowledge of students in a particular subject, and knowledge of subject content representations. Many researchers have subsequently embraced Shulman's ideas and some have further developed the conceptualisation of PCK (e.g. Zembal-Saul et al., 2000).

Even though there have been many PCK models, PCK models proposed for teaching chemistry are seldom reported in the literature. There are, however, PCK models reported for teaching in other disciplines such as English (Grossman, 1989), science (Magnusson et al., 1999) and mathematics (Kinach, 2002). Of these models, the PCK model for teaching science proposed by Magnusson et al. (1999) is suitable for modification for the present work which aims to produce a PCK model for teaching chemistry. Since chemistry is one domain of science, teaching and learning chemistry is related to teaching science. Chemistry, like biology, physics and geology, is a subject of science which has its own concepts, technical terms, and topics, and the teaching and the learning of chemistry is thus unique (Bucat, 2004). PCK in this study is defined as teachers' knowledge that enables them to transform particular chemistry content knowledge into forms that are understandable for a diverse group of students. It consists of teacher beliefs about the nature, teaching and learning of science/chemistry; knowledge of chemistry curriculum; knowledge of student conceptions and learning difficulties in chemistry; knowledge of instructional strategies; and, knowledge of assessment. All these components should be simultaneously developed and integrated to become PCK. The integration of knowledge components reflected what chemistry teachers believe about the nature of science and chemistry, teaching and learning science; and, how they set learning outcomes, elicit students' conceptions, design teaching strategies and materials, and assess students' learning.

Research Methodology

The purpose of this study was to examine the impact of a PCK-based methods course on pre-service chemistry teachers' PCK, and to investigate how they developed and brought their PCK into teaching practice during their teaching field experience. A multi-case study was used, based within an interpretive paradigm (Cohen & Manion, 1994).

Context of the Study

The participants in this study were four pre-service chemistry teachers (pseudonyms; Sopa, Jiranan, Ladawan, and Malee) participating in the Graduate Diploma Programme in Teaching Profession at a university in the Northeast of Thailand. Prior to studying the Diploma Programme, they had gained a science bachelor degree, majoring in chemistry. During the first semester, these pre-service teachers attended the PCK-based chemistry methods course in this study. In the second semester of 2005, the participants were required to practice their student teaching in local schools.

All participants were 23-year old female pre-service teachers. Sopa attended elementary and lower secondary schools in a small suburban school near her home. Throughout her study in this school, she was an outstanding student with the highest grades in her class. Because she liked chemistry, Sopa made a decision to do chemistry as her major subject when studying at university. Unlike Sopa, Malee attended high school in a large city. She was an outstanding young woman who consistently achieved very high grades throughout her educational career. Ladawan studied elementary and lower secondary small suburban school. During her childhood, Ladawan dreamed of being a teacher, because the 'smartest' person in her village was a teacher, and her inspiration. During her high schooling, Ladawan had few opportunities to do science experiments. Most teaching and learning was highly teacher-centered and her high school teachers explained content and gave information to students. Jiranan obtained her four-year bachelor's degree in science majoring chemistry. She spent a year running own business prior to studying in the diploma programme. Jiranan felt that she held a good understanding of chemistry content in high school, especially in electrochemistry, and she thought her creative imagination was a significant factor helping her to gain in-depth understanding.

PCK-based Chemistry Methods Course

The PCK-based chemistry methods course aimed to develop pre-service teachers' PCK for teaching of chemistry. It comprised weekly three-hour classes which ran for 16 weeks. The course aimed to develop pre-service teachers' PCK for the teaching of chemistry and consisted of two blocks: classroom-based activities and school-based activities. In the classroom-based activities, a set of opportunities including classroom discussions on various topics, academic readings on the nature of science, constructivist-based teaching, students' conceptions, direct experience of the instructor's modelling of constructivist-based teaching strategies, analysis of videotaped

classes, and reflecting on participants' own and their peers' teaching. The school-based activities sought to provide the student teachers with opportunities to work with experienced 'cooperating' teachers in a school setting, conducting interviews, and observing teachers' teaching and students' learning in the classroom.

At the beginning of the course, the pre-service chemistry teachers were asked to describe their educational background and their own beliefs about teaching and learning science. They were also required to develop their own lesson plans to teach high school chemistry students. The pre-service chemistry teachers were then encouraged to trial their lessons for teaching chemistry, consider the teaching approaches that would best suit and be relevant to the chemistry topic and grade level, and reflect on the strengths and weaknesses of their teaching. They were encouraged to develop an understanding of science curriculum, student conceptions and learning, methods of assessment and evaluation by relating what they have learned from classroom observations and interviews with cooperating teachers during their school-based activities, to the theory or principles gained during their classroom-based activities. At the end of the course, the pre-service chemistry teachers had a chance to develop their own lesson plans once again for microteaching. After the microteaching, each pre-service chemistry teacher reflected on his/her strengths and weaknesses of their teaching, while their peers and the course instructor gave feedback and suggestions.

Data Collection and Analysis

In order to understand teacher's PCK in three ways (planning, actions, and reasons), multi-method evaluations were used during the research process (Baxter & Lederman, 1999; Lowery, 2002). The methods included classroom observation, interviews, a chemistry concept survey, a beliefs survey and examination of documents (e.g., weekly journal entries, portfolios, lesson plans, worksheets, and reports). Each data source was combined with different data sources in order to enhance validity and cross-checking of the findings (Cohen & Manion, 1994; Patton, 2002). From the data source, the researcher identified specific events and activities that were either representative of the pre-service teachers' knowledge bases or constituted a significant event in the course. The main points related to teachers' knowledge bases taught in each week were summarised. Data were compared chronologically in order to investigate changes over time. Changes of PCK according to the activities were refined and linked together to

formulate themes to explain the meaning of the data. Cross-case analysis (Patton, 2002) was used to make comparisons across the four cases. Their PCK development was compared and contrasted to general patterns and regularities. Similarities and differences were interpreted in the light of information about individual contexts and personal backgrounds.

Research Findings and Discussion

How Does a PCK-Based Chemistry Methods Course Influence the Development of Pedagogical Content Knowledge for Thai Pre-service Chemistry Teachers?

The findings point to the role that learning activities in a PCK-based chemistry methods course can play in helping these pre-service chemistry teachers integrate each component of PCK and transform chemistry content knowledge to better teach their students. At the beginning of the course, the pre-service chemistry teachers held a range of beliefs about the nature of, teaching and learning of science (Cronin-Jones, 1991). Malee and Ladawan thought of science as a body of knowledge, while the others believed that science could be knowledge and the inquiry process used to obtain knowledge. All believed that the scientific method is the only approach to search for scientific knowledge. Their initial beliefs about teaching and learning of science ranged from positivist to constructivist-based views. For example, Ladawan's beliefs were largely based on a positivist view that it was essential to transmit scientific knowledge to students. Sopa and Malee believed that teaching science should be a hands-on, discovery approach. Jiranan's initial beliefs were constructivist in nature, in which learning science meant experiencing things in order to explain natural phenomena.

In their first attempt at lesson planning, the pre-service chemistry teachers showed their limited knowledge base of PCK. Components in their first lesson plans included student learning outcomes, main ideas, learning activities, instructional materials and assessment, but these components were not related to each other. Since the pre-service teachers were students who held science degrees and no education qualifications, it is not surprising that they did not know much about lesson planning or how to organise learning activities. They coped with this by consulting with the Institute of Promotion of Science and Technology Teaching [IPST] teacher and student manuals, chemistry textbooks, and searching for information from the Internet about a form for lesson plans when planning their own lessons. Examination of their lesson plans suggested that the pre-service teachers did not consider learning standards from the Science Curriculum

Framework, were rarely aware of the importance of students' prior knowledge and prerequisite knowledge of chemistry concepts, and student individual differences, and used lectures as teaching strategies, with a focus on conceptual understanding. For instance, in her first lesson plan, Malee chose the topic of conservation of mass for grade 10 students. She began by asking students "what would happen, if we live on the earth and the moon without mass and weight?" Then she distributed documents about mass of chemicals in chemical reactions and asked them to read, but these did not link her question to the subsequent activity. Instead, Malee explained how the mass of chemicals changes before and after chemical reactions. She continued to explain the rule of conservation of matter and gave examples of chemical reactions. Then she distributed worksheets and asked the students to answer questions from the worksheet.

Upon experiencing the PCK-based chemistry methods course, all of the pre-service chemistry teachers gradually developed their PCK. At the beginning of the course, the pre-service teachers had opportunities to read, analyse and discuss guidelines and principles about teaching and learning from the National Education Act, 1999, the Basic Education Curriculum, and the Science Curriculum Framework. These opportunities allowed Sopa, Malee, Ladawan and Jiranan to consider the fundamental ideas about goals of teaching and learning of science, teacher and student roles in science classroom, science curriculum, emphasis on student conception and learning, learner-centered teaching approaches, and assessment modes. For example, Malee reflected extensively on her ideas in journal entries:

> The content in this week is new thing I've learned. This content is about the National Education Act, 1999, Basic Education Curriculum, and Science Curriculum, which are related to each other. In this week, I've learned many things such as the goals and principles of education in these documents, Learning Standards, and teachers' role. (Malee's 2nd week journal)

Consistent with the findings of Peterson and Treagust (1998), the pre-service teachers in the present work were able to develop components of PCK in relation to fundamental ideas discussed in the methods course. In particular, they became aware of conceptual understanding, science process skills, and cooperative group work as learning outcomes, aware of the significance of student prior knowledge and individual differences in learning activities, and a variety of assessment methods and broadened their beliefs to be more constructivist in nature.

Additionally, the pre-service teachers broadened their fundamental ideas from deliberately making connections between classroom-based and school-based activities (Lemberker et al., 1999; Lowery, 2002). They encountered many opportunities to link educational principles and theories in their classroom-based activities in a real classroom setting. Observation of the cooperating teacher's teaching and interviews with the cooperating teachers about school-based curriculum and student learning during school-based activities followed by discussion of these issues in classroom-based activities enhanced the pre-service teachers' curriculum knowledge, and knowledge of student conceptions and learning. The pre-service teachers, especially Jiranan, came to understand science curriculum development and the implementation of basic and advanced science in a real school context. Jiranan thought that she learned nothing from reading the National Education Act, 1999, the Basic Education Curriculum, but working with and interviewing the cooperating teachers helped her understand the goals of teaching science and how to develop school-based curriculum. The pre-service teachers became more aware of the nature of high school students, such as their behaviour, ability, and learning. All felt that their experiences in the schools provided them with opportunities to understand student alternative conceptions and learning difficulties. Sopa stated that:

> Teaching and learning of the cooperating teacher in each class was different even though she taught the same concept. For she taught high ability students, most of teaching is about asking questions, discussion, and complete the test. For low ability students, she would let students work in groups. (Sopa's 7th week report of observation of the school teachers' teaching)

The pre-service teachers' PCK development seemed strongly influenced by role modeling (the course instructor took the role as a school chemistry teacher and the pre-service teachers acted as high school students). The findings suggested that role modeling plays an important part in providing pre-service chemistry teachers with ideas how to integrate each component of PCK (Capobianco, 2007; Lemberker et al., 1999). In the role modeling here, the methods course instructor assumed the role as a high school teacher, and the pre-service teachers took the role of school students. The role modeling activity provided as part of PCK development enabled the pre-service teachers to consider various issues of learning outcomes, student learning and conceptions, constructivist-based teaching strategies,

assessment of student learning and to realise that these should be interrelated in both lesson plans and teaching practice. All of the pre-service teachers seemed to appreciate the role modeling activity, and they noted that they got direct experience about teaching strategies from this activity. For example, Jiranan reflected on instructor's teaching about conservation of mass that:

> For me, I like this teaching strategy [Focus-Action-Reflection guide teaching strategy] so much because it can make me obviously see [particulate nature of particles]. I can see relationship of each concept. I think teaching [in other topics] will be successful like this if we learn to imagine and find out answers from our imagination, for example, what will happen when various molecules react each other, and why different molecules have different shape. (6th week journal)

The pre-service teachers also developed their PCK through reflection. In the methods course, the pre-service teachers had many opportunities such as, writing weekly journal entries, and watching a video of teaching practice to reflect on their own beliefs and teaching practice, and others' teaching. Reflection on their own teaching and others' teaching by watching the video of teaching practice and discussing issues related to PCK teaching helped the pre-service teachers see their progression on teaching and limitations of their own teaching, and identify useful alternative activities from observations of others' teaching. As Jiranan and Malee stated:

> From my peers' teaching, I've learned problems appeared in the classroom and if this situation happened in my class, how should I do. I have learned various strategies from suggestions of other friends such as classroom management, instructional media, and teaching strategies. I can apply all these issues in my future teaching. (Jiranan's 5th week journal)

> After watching the video of my teaching, I know that I need to improve my teaching to be better than that. I need to improve the classroom introduction, using the instructional materials, trying to foster students have better understanding. I should remember students' names and have eyes contact with them. (Malee's 5th week journal)

These findings are consistent with work by Zembal-Saul *et al.* (2000), who suggest that reflection on teaching appears to help pre-service teachers in identifying and examining key issues associated with their teaching, and

developing an initial framework for thinking about the complexity of learning and content.

Through the learning activities mentioned above, the pre-service teachers were subsequently able to incorporate what they learned about PCK into their second lesson plans and into the microteaching at the end of the methods course. Examination of their second lesson plans and observation of microteaching indicated that the pre-service teachers could indeed integrate PCK components for teaching particular chemistry topics. Their second lesson plans had more detail about learning outcomes, the learning activities sequence, instructional media, and assessment methods. In her second lesson plan, for example, Malee expected her students to be able to: provide a definition of system and environment; classify types of systems; conclude that when the mass of matter changes in a closed system the mass before and after reaction would be equal and, work cooperatively in groups. In order to meet these learning outcomes, Malee explained that she designed learning activities using the Generative Learning Model. She planned to elicit students' prior knowledge about system and environment by using Interview-About-Instance technique and link their prior knowledge of a closed system to the concept of changes of mass in chemical reaction. The instructional media were information documents about system and environment, a worksheet, an assignment, an evaluation form of cooperative learning, and exemplars. Malee used observation, classroom participation, worksheet, and an evaluation form of cooperative learning as assessment and evaluation of student learning.

Their lesson plans improved compared to the first lesson plans, in which each component was interrelated. All of the pre-service teachers appeared to focus more on cooperative learning as a dimension of student learning, and used constructivist-based teaching strategies and a variety of assessment methods. When they brought their PCK into microteaching, at the beginning of the lesson, all of the pre-service teachers except Ladawan, tried to elicit student prior conceptions of particular chemistry concepts. Their learning activities seemed to be based on constructivist-based teaching and learning. However, they struggled to link student prior conceptions to the rest of the learning activities. Rather than providing students with hands-on activities to facilitate students' understanding from prior knowledge to scientific concepts, the pre-service teachers provided explanations after eliciting students' prior knowledge. This contradiction might have occurred because

the microteaching exercise was their first teaching experience; hence, the pre-service teachers were not familiar with their students and needed time to improve their teaching ability and techniques (Bell & Gilbert, 1994).

How Do Pre-service Chemistry Teachers Develop Their PCK During Their Field Experience?

The research findings highlight an interesting issue of how the pre-service chemistry teachers transferred their PCK from the methods course into classroom practice, and provide an in-depth understanding of the sustainability of the pre-service teachers' PCK. When the pre-service teachers' teachings in real classrooms were observed, it seemed that the PCK-based chemistry methods course had a strong influence on the pre-service teachers' PCK (Beeth & Adadan, 2006). The pre-service teachers thought that experiencing in planning chemistry lessons and micro-teaching enhanced their teaching ability. In their view, and understanding of lesson planning and organising learning activities appropriate with chemistry content and student-centred learning can be applied in a real situation. Additionally, they valued the methods course as a place where they were able to relate these experiences in teaching chemistry and were able to relate these experiences to other learning from other courses. For example, Jiranan said that:

> First of all I need to apologise that last semester I blamed and commented you [the methods course instructor] many things. I want the say that from all course of the diploma in teaching programme, I can say about ninety-eight percent of my teaching I brought what I've learned from the methods course. I think the contents I've learned in other course didn't mean anything. I think if I didn't learn these courses, I still can teach. (Jiranan's 6th interview)

The pre-service teachers appropriately incorporated their methods course learning into their student teaching experience. All pre-service teachers, except Ladawan who followed the lesson planning from her cooperating teachers, planned chemistry lessons by applying a form of lesson plans from the methods course. They thought that using this form helped them easily identify whether the components of the lesson plan were interrelated. When planning the chemistry lessons, the pre-service teachers understood the importance of students' learning styles and their needs. They asked their students about what they learned in the previous chemistry courses, what they wanted to learn, and what teaching styles they liked.

When the pre-service teachers implemented their lesson plans, the classroom teaching was influenced by their beliefs about teaching and learning science. They came to their field experience with these beliefs from the methods course and these beliefs seemed to be sustained throughout the field experience. For example, Jiranan's teaching was student-centred in nature because she believed in constructivist views of learning, in that, students held prior knowledge before coming to the classroom and teaching science should relate to their everyday lives. Jiranan tried out her ideas many times and she adjusted student-centred learning activities to meet the needs of her students. She elicited student conceptions about chemistry concepts related to their daily lives, asked the students to do hands-on activities together with classroom discussion. She assessed student learning by considering students' summary of what the students had learned about chemistry concepts and observing students' responses and interactions during learning activities. In contrast, Ladawan's beliefs about transmission of knowledge drove her to use lectures in which she asked students to complete worksheets and gave them the correct chemistry concepts. Ladawan assessed student learning by only checking whether or not the students handed in their assignment. Throughout her field experience, Ladawan did not attempt constructivist-based views of learning she learned from the methods course in her teaching.

However, some pre-service teachers' beliefs were not sustained throughout their field experience. In the case of Sopa and Malee, their teaching was mixed between positivist and constructivist views. Even though they felt that student prior knowledge and hands-on discovery approach were important in their learning, as the field experience progressed, their beliefs became more positivist views. They thought that student-centred learning did not work in a real situation. Sopa and Malee tried to draw upon their beliefs about student-centred learning at the beginning of their field experience. However, they stopped when they became concerned with misbehaviour and got few responses from students. Most teaching sequences of Sopa and Malee began by eliciting student prior knowledge and engaging their interests, followed by explanations and lectures. They assessed student learning by observing students' attendance, their answers during classroom discussion, and homework.

A number of factors hindered the implementation of the pre-service teachers' lesson plans in teaching practice. Content knowledge has been

reported to limit teachers' ability to create and implement constructivist-based teaching strategies (see, e.g., Davis & Petish, 2005; Sadler, 2006; Watson, 2006). Ladawan was inadequately prepared in her chemistry courses while pursuing the undergraduate study at the Faculty of Science. Classroom observations and interviews after teaching also suggested that the pre-service teachers held some alternative conceptions in chemistry. She stated that:

> I had only 60 percent in my teaching because some topics I really did not understand. This was my limitation but I did my best. It's difficult especially topics of structure of compounds. (Ladawan's 4th interview)

Ladawan's teaching was mostly based on the transmission of knowledge and some transmitted alternative conceptions to their students. She often prepared herself short notes about the chemistry concepts she was going to teach. She came to the classroom with such notes and often read them while teaching. Ladawan also struggled to ask students content-specific questions. At the beginning of the lesson, she often asked students questions, but most of questions were quite difficult to answer, such as "What organic compounds do you know from your daily lives?" and "Do you know what are the advantages of amine and amide compounds?". When the students could not answer these questions, Ladawan gave correct answers, rather than asking other simple questions or trying other teaching techniques to engage students or help them respond to her questions.

The concerns and struggles in the teaching practice of these pre-service teachers might be addressed if they received ongoing support from their cooperating teachers and university faculty. The literature suggests that support from classroom teachers and university supervisors influenced pre-service teachers' PCK and provide a key component of pre-service teachers' perceived success in their teaching practice (Black, 2004; Sadler, 2006). Unfortunately, the findings of this study indicated that most of these cooperating teachers and university staff left the pre-service teachers pretty much to their own devices. They rarely observed or commented on the pre-service teachers' teaching. Even though there were seminars to discuss the development of their teaching, the pre-service teachers felt that the discussion did not support development of content-specific PCK. Most discussions involved general problems such as student misbehaviour, classroom management, and conflict with the cooperating teachers.

Recommendations

A number of recommendations are derived from the findings of this study. First, this study suggests that a PCK-based chemistry methods course can significantly impact on pre-service chemistry teachers' development of PCK (Beeth & Adadan, 2006; Lemberker *et al.*, 1999). It has the potential to serve as a bridge for pre-service chemistry teachers to integrate content knowledge learned from the Faculty of Science with the knowledge of curriculum, pedagogy, student learning, and assessment. There are four main learning experiences that are important to include in such a methods course. These are analysing and discussing the fundamental ideas and principles of constructivist views of learning; participating in both classroom-based and field-based activities; participating in role modeling; and planning, microteaching and reflection on teaching. These can enhance pre-service science teachers' PCK most effectively when they are integrated, rather than taught separately.

Second, the field experience seems to be an essential component of any teacher preparation programme. It has a significant role in assisting the pre-service teachers gain the expertise and confidence in their teaching. Unfortunately, in the current study, the pre-service teachers struggled in bringing their PCK in teaching practice. They had to solve many of their problems themselves during the field experience. Ongoing support by cooperating teachers, and university supervisors rarely appeared (Sadler, 2006). To assist pre-service teachers' development of PCK, cooperating teachers and university supervisors need to clearly understand their roles and duties. They should provide pre-service teachers with opportunities to test their personal beliefs, refine, and reconstruct these theories, with meaningful supports and guidance.

Finally, future research could investigate developing exemplary interventions such as seminars, workshops, or conferences that enhance pre-service science teachers' PCK in their teaching practice. In exemplary interventions, pre-service science teachers may work with their peers, students, cooperating teachers and university supervisors to collaboratively conduct their own action research. Since the collaborative action research can be a tool to help pre-service science teachers reflect on their PCK during their field experience, it could encourage their understanding of constructivist-based teaching and learning in both theory and actions. This type of future research could provide science educators, university

supervisors, cooperating teachers, and stakeholders with the data about an effective intervention and a theoretical base, and guide the preparation of science teachers.

References

Abell, S. K. & Bryan, L.S. (1997). Reconceptualizing the elementary science methods course using a reflection orientation. *Journal of Science Teacher Education*, *8* (3), 153-166.

Baxter, J.A. & Lederman, N.G. (1999) Assessment and measurement of pedagogical content knowledge, in: J. Gess-Newsome & N. G. Lederman (Eds). *Examining pedagogical content knowledge (pp. 147-161.)* Netherlands: Kluwer Academic Publisher.

Bell, B. & Gilbert, J. (1994). Teacher development as professional, personal, and social development. *Teaching and Teacher Education*, *10* (5), 483–497.

Beeth, M.E. & Adadan, E. (2006). The influences of university-based coursework on field experience. *Journal of Science Teacher Education*, 17, 103-120.

Black, K. (2004). Science in the trenches: An exploration of four pre-service teachers' first attempts at teaching science in the classroom. *International Journal of Science and Mathematics Education, 2*, 25-44.

Bucat R. (2004). Pedagogical content knowledge as a way forward: Applied research in chemistry education. *Chemical Education: Research and Practice*, *5* (3), 215-228.

Capobianco, B. M. (2007). A self-study of the role of technology in promoting reflection and inquiry-based science teaching. *Journal of Science Teacher Education*,*18*, 271–295.

Cobern, W. (1993). The construction of knowledge: A radical constructivist view, in: K. Tobin, (Ed). *The practice of constructivism in science education (pp. 51-69)*. Washington D.C.: AAAS Press.

Cohen, L. & Manion, L. (1994). *Research Methods in Education Fourth Edition*. London: Routledge.

Cronin-Jones, L.L. (1991). Science teaching beliefs and their influence on curriculum implementation: two case studies. *Journal of Research in Science Teaching*, *28* (3), 235-250.

Davis, E. & Petish, D. (2005). Real-world applications and instructional

representations among prospective elementary science teachers. *Journal of Science Teacher Education*, *16*, 263–286.

Faikhamta, C. & Roadrangka, V. (2005). Problems in professional experience training of student teachers in the Project for the Promotion of Science and Mathematics Talented Teachers (PSMT). *Songklanakarin Journal of Social Sciences and Humanities, 11* (2), 151-164.

Geddis, A.N., Onslow, B., Beynon, C. & Oesch, J. (1993). Transformation content knowledge: learning to teaching isotopes. *Science Education*, *77* (6), 575-591.

Grossman, P.L. (1989). A study in contrast: Sources of pedagogical content knowledge for secondary English teachers. *Journal of Teacher Education*, *40* (5), 24-31.

Kinach, B.M. (2002). A cognitive strategy for developing pedagogical content knowledge in the secondary mathematics methods courses: toward a model of effective practice. *Teaching and Teacher Education*, *18* (1), 51-71.

Lemberker, J., Hewson, P.W., & Park, H. (1999). Relationships between prospective secondary teachers' classroom practice and their conceptions of biology and of teaching science. *Science Education*, *83* (3), 347-371.

Lowery, N.V. (2002). Construction of teacher knowledge in context: Preparing elementary teachers to teach mathematics and science. *School Science and Mathematics*, *102* (2), 68-83.

Magnusson, S., Krajcik, J., & Borko, H. (1999). PCK and science education. In: J. Gess-Newsome & N. G. Lederman (Eds). *Examining pedagogical content knowledge* (pp. 95-132). Netherlands: Kluwer Academic Publisher.

Office of the National Education Commission. (1999). *National Education Act 1999*. Bangkok: Office of National Education Commission.

Patton, M.Q. (2002). *Qualitative research and evaluation methods*. California: Sage.

Peterson, R.F. & Treagust, D.F. (1998). Learning to teach primary science through problem-based learning. *Science Education*, *82*, 215-237.

Pillay, H. (2002). *Teacher development for quality learning: The Thailand education reform project*. Bangkok: Office of National Education Commission.

Sadler, T. D. (2006). "I Won't Last Three Weeks": Pre-service science teachers reflect on their student-teaching experiences. *Journal of Science Teacher Education*, *17*, 217-241.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(1), 4-14.

The Institute of Promotion of Science and Technology Teaching. (2002). *Thai science teachers standards*. Bangkok: The Institute of Promotion of Science and Technology Teaching.

Tobin, K., Tippins, D.J., & Gallard, A. J. (1994) Research on instructional strategies for teaching science in D.L. Gabel (Ed.) *Handbook of research on science teaching and learning (pp.45-93).* New York: Macmillan.

Watson, S.B. (2006). Novice Science Teachers: Expectations and Experiences. *Journal of Science Teacher Education*, *17*, 279–290.

Zembal-Saul, C., Blumenfeld, P., & Krajcik, J. (2000). Influencing of guided cycles of planning, teaching and reflection on prospective elementary teachers' science content representation. *Journal of Research in Science Teaching*, *37* (4), 318-339.