THESIS APPROVAL
GRADUATE SCHOOL, KASETSART UNIVERSITY

Doctor of Philosophy (Science Education)

DEGREE

Science Education

FIELD

Education

DEPARTMENT

TITLE: Enhancing Elementary Science Teachers' Pedagogical Content Knowledge through a Co-Teaching Model

NAME: Miss Siriwan Chatmaneerungcharoen

THIS THESIS HAS BEEN ACCEPTED BY

THESIS ADVISOR

(Assistant Professor Naruemon Yutakom, Ph.D.)

THESIS CO-ADVISOR

(Assistant Professor Kantimanee Pradermwong, Ph.D.)

THESIS CO-ADVISOR

(Professor Gaalen Erickson, Ph.D.)

DEPARTMENT HEAD

(Assistant Professor Sudarat Sarnswang, Ph.D.)

APPROVED BY THE GRADUATE SCHOOL ON

DEAN

(Associate Professor Gunjana Theeragool, D.Agr.)

THESIS

ENHANCING ELEMENTARY SCIENCE TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE THROUGH A CO-TEACHING MODEL

SIRIWAN CHATMANEERUNGCHAROEN

A Thesis Submitted in Partial Fulfillment of

the Requirements for the Degree of

Doctor of Philosophy (Science Education)

Graduate School, Kasetsart University

2011

Siriwan Chatmaneerungcharoen 2011: Enhancing Elementary Science Teachers' Pedagogical Content Knowledge through a Co-Teaching Model. Doctor of Philosophy (Science Education), Major Field: Science Education, Department of Education. Thesis Advisor: Assistant Professor Naruemon Yutakom, Ph.D. 411 pages.

Pedagogical Content Knowledge [PCK] is essential to career development for teachers. Competencies that science teachers must master represent the blending of content and pedagogy which should result in increased understanding for students. Therefore, the purpose of the study is to enhance elementary science teachers' pedagogical content knowledge through a Co-Teaching Model [CTM]. In addition, the researcher aims to develop the effective characteristics of co-teaching model supporting science teachers' changes to their PCK. Three volunteer science teachers in grade 4-6 at the same school participated in this study for 1 year. A CTM was used as a professional development [PD] program. Data sources throughout the research project consisted of classroom observations, individual interviews, questionnaires and document analysis. Inductive analysis was used to analyze the data into more general outcomes in which were presented in three case studies and a cross-case analysis.

Findings indicate that before the three teachers were engaged with CTM they experienced some problems regarding: articulating the purposes for teaching science, designing appropriate instructional and assessment activities, understanding the science content, and how their students approached the learning of the science content in the curriculum reform. Even though the three teachers realized that many aspects of their teaching practice needed to be altered to address the curriculum reform in science teaching, the areas of greatest need were to develop a better understanding of articulating the purposes for teaching science, the curriculum content and broaden their teaching approaches. After the three teachers participated in CTM, the results showed that their performances in developing PCK, as assessed by the design of their inquiry-based lesson plans and as observed in their classroom practices, shifted from teacher-centered to student-centered teaching and learning practices. The sustained production of inquiry-based lesson plans and practices demonstrates that teachers gradually accepted the CTM as method of PCK development. They changed their understandings and practices about subject matter knowledge, pedagogical knowledge and knowledge of context gradually. Evidence from this study indicates that the incorporation of the CTM within a professional development program is useful for promoting the teachers' understandings and practices of PCK in classroom settings. Further, this study found that the main factor affecting teacher's development of their PCK was institutional support. The implication of this study are that institutions responsible for producing and developing science teacher should create and provide a long-term PD program for enhancing the teacher's PCK by encouraging them to share, discuss, and reflect their knowledge. The present study did not focus on the role of administrator; therefore, further research is needed to understand how school and district administrators can promote effective PD program for elementary science teachers.

______________________________ ______________________________ ___ / ___ / ___

Student's signature Thesis Advisor's signature

ACKNOWLEDGEMENTS

My success would not be happened if I did not have the help, guidance and assistance of so many people. First, I would like to express my deepest thanks to my advisor Assistant Professor Dr. Naruemon Yutakom for her meaningful suggestions and tremendous encouragement throughout the whole thesis. I would like to express my gratitude to Assistant Professor Dr. Kantimanee Phanwichien who is my co-advisor and my inspiration to be a good teacher. She guided me through many opportunities in my life. I also wish to extend a special thanks to Professor Dr. Gaalen Erickson who helped and advised while studying at the University of British Columbia [UBC] in Canada and also when I returned to Thailand. I am indebted to the Institute for the Promotion of Teaching Science and Technology [IPST], Thailand for providing me the scholarship to study from a bachelor degree through to a doctoral degree. I also wish to express my gratitude to the Graduate School, Kasetsart University for all the funding support. Furthermore, this thesis would not have been completed without the support from the group of experts, research participants, and school administrators. I would like to thank all of the English editors and especially my husband, Robert Kief, for his patience and devotion in proof reading my writing.

I am so appreciative of teachers and friends in the Program to Prepare Research, and Development Personnel for Science Education for their help, guidance and advice throughout my Ph.D. study. Profoundly, my heartfelt gratitude goes to my parents and family who supported me throughout my educational career. I also wish to thank my beloved sister and brother who stood beside me whenever I needed help. Finally, I would like to dedicate this thesis to my mother, who worked hard throughout her life for me. Regrettably she passed away before the completion of this thesis. Without the support of my parents, I would not stand at this point. They continuously encouraged me to strive for the best that I could achieve so that future Thai citizens would benefit from my accomplishments.

Siriwan Chatmaneerungcharoen
April, 2011

TABLE OF CONTENT

TABLE OF CONTENT (CONTINUED)

Page

TABLE OF CONTENT (CONTINUED)

TABLE OF CONTENT (CONTINUED)

Page

TABLE OF CONTENT (CONTINUED)

TABLE OF CONTENT (CONTINUED)

TABLE OF CONTENT (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The first chapter of this thesis describes the problem area of the study which is the basis for the research objectives and research questions. Then the research objectives and research questions are described in more detail. This is followed by a section on operational definitions of terms and the last section concludes by outlining the remaining chapters of this thesis.

Statement of the Problem

Background to the Problem Area

Education has an immense impact on the human society. The enactment of the National Education Act of B.E. 2542 (1999) and Amendments to the Second National Education Act of B.E. 2545 (2002) stated that the goals of education are fully developing Thai people in all aspects: "physical and mental health; intellectual knowledge; morality; integrity; and a desirable way of life so as to be able to live in harmony with other people" (Office of the National Commission [ONEC], 2002). Scientific and technological knowledge are integral to modern society. Science enables people to understand natural phenomena and leads to specific knowledge and development of technologies that respond to human needs and solve human problems. The Thai government has been challenged to think about factors that would stimulate national policies for developing the country socio-economically, environmentally, and culturally. The economic crisis reveals that Thailand has deficiencies in many areas including science and technology (ONEC, 2001). The Ninth National Economic and Social Development Plan (National Economic and Social Development Board [NESDB], 2002) emphasize the development of science and technology for the enactment of economic fundamental policy. The development presented that education has a strong relationship with science and technology in the development of science and technology literacy for all Thai citizens. Moreover, the National Science Education Standards present a vision of a scientifically literate populace. These standards claim all students can demonstrate high levels of performance; teachers are empowered to make the decisions essential for effective learning, and encourage collaborative communities of teachers and students to focus on learning science. Therefore, teaching and learning for Thai citizens is conducted through a learner-centered approach considered central to educational reform (ONEC, 2002a).

In the process of developing competent citizens, teachers play an important role in educational reform and science education (ONEC, 2001; Pongsopon, 2003; Pitiyanuwat, 2004; Roadrangka, 2004). In Thailand, teachers are widely accepted as the heart of the learning reform because they are the most significant and indispensable component in the teaching and learning processes occurring in classrooms (Office of Rajabhat Institute Council, 2002). Teachers additionally play an important role in facilitating learning and development of students who are regarded as an indicator of success in economy, society, politics, education, culture, science and technology development (Pornsrima, 2002) and an important resource of the nation in the future (Secretariat of the Teacher Council, 1994).

The national requirements for teacher preparation and development seek to encourage teachers to organize the learning process. The success of educational reform depends on the quality of teachers and their cooperation (Jurawatanaton, 2003). Nevertheless, the quality of in-service teachers has regressed considerably in recent years (Sinlarat, 1999). Thailand attaches great importance to improving the status and quality of teachers and education personnel. The teacher acts as a facilitator who provides students with activities to change them from any alternative conceptions to scientific conceptions. The facilitator also has roles in: discovering what the students are thinking; helping students to clarify and to reflect on their own ideas; challenging student's ideas; developing school–based science curriculum, planning lessons, developing instructional media; and assessing and evaluating student learning, and so on. The role of the teacher as facilitator and the learner-centered approach, based on constructivist-based teaching and learning perspectives, will contribute to the success of learning reform in Thailand (OEC, 2004). According to Pillay (2002) and Narot (2004), Thai teachers lack an understanding of the concept, principles, and processes involved in these new approaches of teaching and learning and also have negative attitudes towards the new methods. Pillay (2002:15) also notes that:

> …As opposed to simply transmitting knowledge, teachers need to conceptualize knowledge as a personally constructed entity of the learner and to understand that their role is to facilitate this construction process. They need to appreciate the complex multidimensional nature of knowledge and know how to break down the subject content and process to make it simple and enjoyable for children to learn.

This means that teachers need to gain knowledge of such teaching and learning methods and believe in them. According to research by Pruet Siribanpitak (2004), many teachers do not have qualifications that match the subjects they teach, and out-of-field teaching adds to the difficulties in critical subjects. Teachers have difficulties in implementing constructivist-based teaching and learning approaches. These approaches are seen to be radically new for the majority of science teachers and they are suspicious of their effectiveness. Particularly, there are numbers of studies document the problems in-service elementary science teaching (ONEC, 2001; Yutakom and Chaiso, 1999). Thai elementary school teachers often have not enough pedagogical content knowledge necessary to create a constructivist classroom. Moreover, most in-service science teachers did not graduate in science (Thongkrai, 2000; ONEC, 2001). The data from the Office of National Primary Education (1994) pointed out that only 7.7 percent of all teachers graduated in science (ONEC, 2001). This causes them to be weak in science content and skills, with a resulting lack in confidence and competence when teaching science. Elementary science teachers with low confidence cope by only teaching the minimum required and stressing aspects in which they feel more confident. For example, they may use prescriptive texts, underplay questioning and discussion, and perform only simple practical work with basic equipment. When these coping strategies become the norm, pupils' academic attainment is limited (Osborne and Simon, 1996; Harlen and Holroyd, 1997). Most importantly, they lack an understanding about how to represent science content in ways that are personally meaningful and potentially accessible to students; in other words, they lack pedagogical content knowledge [PCK] (Tobin and McRobbie, 1999; Raizen and Michelsohn, 1994 cited in Kelly, 2000). In Thai education an inquiry approach is the main strategy for teaching science following constructivist approaches. The National Science Education Reform advocates that science teachers should engage students in doing and thinking about inquiry, and renew emphasis on teaching about the nature of science (Institute for Promotion of Teaching Science and Technology [IPST], 2002b). Most in-service science teachers have a vague meaning of scientific inquiry in the classroom that has taken on different forms; while researchers and teacher educators may have very different views and practices (Crawford, 2000). These are some of the reasons as to why science teachers cannot shift toward more learner-centered and more inquiry-centered K-12 classrooms. Therefore, the main factor that supports creating a more ‘learner-centered classroom environment is the teacher’s pedagogical content knowledge. In particular, this issue can be related to the Thai context since recent low achievement in science was evidenced in every subject in Thailand’s National Test, taken by students at the end of grades 3, 6, 9 and 12. In order to provide students with opportunities and activities to learn science in line with these educational reform guidelines, it is suggested that science teachers use the teaching approach associated with student-centered learning (OEC, 2004).

Research Questions and Research Objectives

This study examines the enhancement of elementary science in-service teachers’ pedagogical content knowledge [PCK] through the co-teaching model [CTM]. The research objectives are expressed through the following research questions.

Research Question 1

1. What are the understandings and practices of elementary science teachers’ PCK prior to participating in the CTM?

1.1 What are teachers' understandings and practices about subject matter knowledge?

1.2 What are teachers' understandings and practices about pedagogical knowledge?

1.3 What are teachers' understandings and practices about knowledge of context?

Research Question 2

2. What were the characteristics of a CTM that appeared to be the most effective in bringing about changes in the teachers' PCK?

Research Question 3

3. What are some of the characteristics of the PCK developed by elementary science teachers when engaging with the CTM?

3.1 Do any changes occur in the teachers' understandings and practices about subject matter knowledge?

3.2 Do any changes occur in the teachers' understandings and practices about pedagogical knowledge?

3.3 Do any changes occur in the teachers' understandings and practices about knowledge of context?

Research Question 4

4. What do factors constrain or support the elementary science teachers' implementation of the CTM?

Research Objectives

This research aims to:

1. Document elementary science teachers' current pedagogical content knowledge

2. Examine the development of elementary science teachers' pedagogical content knowledge when engaging in a co-teaching model.

3. Explore the factors that support or obstruct elementary science teachers in developing their pedagogical content knowledge during their implementation of the co-teaching model.

Anticipated Outcomes

At the completion of this study, the researcher expects the anticipated following outcomes:

1. This study might be useful for professional developers to generate new programs that provide an opportunity to develop elementary science teachers' pedagogical content knowledge that relies heavily on national education goals.

2. Professional developer will have an exemplary model of professional development through co-teaching for enhancing elementary science teaching practices by developing teachers' pedagogical content knowledge and effective practice.

Definition of Terms

Four important terms introduced in this study are operationally defined as follows:

Pedagogical Content Knowledge [PCK] is referred to a specific category of knowledge for teaching science that is conceptualized as a blend of content knowledge into pedagogical knowledge for application these knowledge realizing on context to enables science teachers to transform particular content knowledge into form that is understandable for diverse group of students. The first component of PCK is regarded on understanding and practice of science content; the second aspect is understanding and practice on pedagogical knowledge that also has five subtopic (the purposes for teaching science, instructional strategy, learner and learning, science curriculum, and science learning assessment); and the last component of PCK for the study is understanding and practice of context (community, school, and student). The PCK's elements are intertwined and should be used in a flexible manner. The more representations teachers have at their disposal and the better they recognize learning difficulties, the more effectively they can deploy their PCK.

Teaching Science by Inquiry is largely defined by the teacher's practice in the classroom. From a pedagogical perspective, inquiry-oriented teaching reflects the constructivist model of learning, often referred to as active learning. Teaching science by inquiry is referred to a teaching approach in science subject that comprises of four aspects of its essential features involving the role of the teacher, the role of the students, the instructional objective, and the instructional process. These essential features are derived from the goals of science teaching and learning, the role of teachers and students in science classroom, and the inquiry-oriented activities suggested by the NSCS (DCID, 2002: 3, 35-36), the 5Es inquiry process guided in the Manual of Science Teaching and Learning (DCID and IPST, 2002: 79-80), the scientific inquiry defined by the NSES (National Research Council, 1996: 23) and the essential features of classroom inquiry (National Research Council, 2000: 24-27) . In classrooms where students are encouraged to make meaning, they are generally involved in developing and restructuring their knowledge schemes through experiences with phenomena, through exploratory talk and teacher intervention (Driver, 1989). The role of inquiry teacher is a guide, a facilitator, a motivator, and a researcher for students' learning. Therefore, the features of classroom inquiry are as follows:

a) Learners are engaged by scientifically oriented questions.

b) Learners give priority to evidence, which allows them to develop explanations that address scientifically oriented questions.

c) Learners formulate explanations from evidence to address scientifically oriented questions.

d) Learners evaluate their explanations in light of appropriate explanations, particularly those reflecting scientific understanding.

e) Learners communicate and justify their proposed explanations.

Elementary In-Service Science Teachers are persons who are teaching in the upper elementary level (Level Standard 2, grade 4-6) of public schools.

Co-Teaching Model [CTM] is referred as a professional development program established in this study. It aims to enrich elementary science teachers' understanding and practice of PCK in their own classrooms. The CTM emphasizes collaboration and communication among all members of a team to meet the needs of all students. A CTM team consists of researcher, science educator and three elementary science teachers. The team comes together for a common purpose, typically to teach a wide range of learners more effectively. Keys to successful co-teaching include co-planning, disposition, teaching and evaluating. All members of the CTM share a goal in developing the two teachers' practices of teaching in science concept through an inquiry-based approach. The CTM is designed based on a number of principles consistent with the desirable features of teacher professional development program in Thailand. These features include: a) having long-term support for teachers both in groups and as individuals, b) conducting in teachers' actual classroom, c) encouraging teachers to change their practice, d) being part of the teachers' regular duties, e) promoting collaboration between teachers and the program facilitator, f) empowering teachers' sense of ownership, g) requiring teachers' willingness, and h) working in a friendly atmosphere (OEC, 2004; Puntumasen, 2004).

Summary

Thailand promulgated the National Education Act as the first comprehensive education law in 1999. The main objective of this Act is to improve the quality of Thai learners. Therefore, this Act requires the teaching profession to be developed on a continuous basis and emphasizes the shifts in pedagogical practices away from the teacher-centered toward the learner-centered approach. The heart of education reform is teachers who play a significant role to develop the quality of learners. It is therefore essential for the development of individual teachers to be able to reform the learning process in accordance with the requirements of a knowledge-based society in order to improve the quality of learners or students to their full potential. Thai science teachers need to use teaching approaches associated with constructivist-based views of learning. They have to shift their role away from a director towards a facilitator.

Science teachers attempt to acquire knowledge for teaching which is called pedagogical content knowledge [PCK] because this knowledge helps them to create constructivist classrooms and provides the opportunity for their students to learn science through an inquiry approach. The PCK has been described as the hallmark of teaching and PCK has become a central focus in learning how to teach particular subjects. In the Thai context, school-based training is a new paradigm to develop the teachers and the teaching profession as well as in-service professional development that contributes to the success of the learning reform in Thailand. In responding to the demand for capable Thai science teachers, the co-teaching model will be designed for the development of science elementary teachers' PCK. This study sought to investigate how elementary in-service science teachers developed and brought their PCK into teaching practice in their classrooms through the co-teaching model. The findings provide an in-depth understanding of whether or not elementary in-service science teachers' PCK is developed from the co-teaching model and whether or not it is sustained.

Overview of the Study

To provide a reader an overview of coming chapter, the following paragraphs provide the conclusions of each coming chapters that explains important components to guide this research study. These components include the context of the study, theoretical perspectives, epistemology, methodology, and finding and discussion.

Chapter 2, a literature review, provides the reader with an understanding of a Thai teacher education context which includes the details of the National Education Acts B.E. 2542 (1999), and details of teacher development. This section describes the National Education Act B.E. 2542 (1999) and Amendments (Second National Education Act B.E. 2545 (2002)). The theoretical perspective and epistemology part provides a description of constructivist theory based for the teaching-learning reform in Thailand. The constructivist theory describes how people construct their knowledge by interacting with the physical and social world (Fosnot, 1996). This theory is implemented to guide this study to determine what and how elementary science teachers construct teachers' PCK in and after engaging with the co-teaching model. Teachers' pedagogical content knowledge and professional development for science education also present with this chapter. Particularly, literatures of co-teaching models are described in this section. These topics are proposed to outline and provide an understanding of theoretical perspective of this study.

Chapter 3, research methodology, describes grounded theory that is used to guide the research process. Activities that are used in CTM are presented in this chapter too. A variety of research methods such as interview, classroom observation, questionnaires and documents are presented in this chapter. Data collection and analysis are described to present how data is collected and analyzed in each phase of the study.

Chapter 4 consists of three case studies which provide the results to address research questions: "What are the understandings and practices of elementary science teachers' pedagogical content knowledge prior to participating in the CTM?" and “what are some of the characteristics of the pedagogical content knowledge developed by elementary science teachers when engaging with the CTM?”

Chapter 5 provides the findings of a cross cases analysis to determine whether there are any common patterns across the cases regarding changes in the teachers’ PCK. In doing so it addresses the other two research questions: “What were the characteristics of a co-teaching model that appeared to be the most effective in bringing about changes in the teachers’ pedagogical content knowledge? And what factors constrain or support elementary science teachers while implementing with the co-teaching model?”

Chapter 6 presents the conclusions, discussion and recommendations of the study, in particular as they relate to issues associated with the professional development of science teachers in Thailand.

CHAPTER II

LITERATURE REVIEW

Overview of the Chapter

The first and second sections of this chapter comprise a literature review of the teaching and learning reform and the National Education Act and science education in Thailand. The third section is a review of pedagogical content knowledge where dimensions of PCK are reviewed. The objective here is to discuss the purposes of PCK and its impact on science teacher education and student learning. The components of PCK are discussed and used to guide the researcher towards a definition and model for PCK suitable for the Thai educational context. Then the literature on developing teachers' PCK is reviewed focusing on the variety of strategies and contexts used in teacher education programs to promote in-service teachers' PCK. Several guiding principles in developing a PCK-based intervention for Thai in -service teachers are outlined. The last section is a review of profession development. The strategies for professional development and professional development in Thailand are discussed. The empirical literature on co-teaching model is examined and used to create a potential model for use in this study as an intervention to improve teacher knowledge.

The Teaching - Learning Reform and the National Education Act B.E. 2542 (1999) and Amendments (Second National Education Act B.E. 2545 (2002))

In 1997, after a decade of serious financial and industrial development, Thailand suffered an economic crisis. In response to this predicament, King Bhumipol proposed a philosophy known as Sufficiency Economy Philosophy [SEP] to address the root of the problem at the educational level.

According to Krongkaew (2003), the philosophy can be summed up in one paragraph as follows:

> …Sufficiency Economy is a philosophy that guides the livelihood and behaviour of people at all levels, from the family to the community to the country, on matters concerning national development and administration. It calls for a 'middle way' to be observed, especially in pursuing economic development in keeping with the world of globalization. Intelligence, attentiveness, and extreme care should be used to ensure that all plans and every step of their implementation are based on knowledge. At the same time we must build up the spiritual foundation of all people in the nation, so they are conscious of moral integrity and honesty and they strive for the appropriate wisdom to live life with forbearance, diligence, self-awareness, intelligence, and attentiveness.

The economic, political, cultural and social crisis is the important factor driving the reform in Thai education. The urgently needed reform is intended to rescue the country from the downward spiral, and education is a major tool for developing the quality of Thai people. The fact of the crisis has brought the re-examination of the country's human resource development system and set the stage for across the board reform of Thai education. Recognizing the urgent need for education reform, the government, acting through the Office of the National Education Commission [ONEC] under the Prime Minister's Office, has formulated policies and plans to bring about necessary changes within the Thai system. ONEC has also prepared legal provisions on education for consideration of the Constitution Drafting Council with the results that the 1997 Thai Constitution contains extensive provision for education, including equal rights for a 12-year basic education program that is of sufficient quality and is free of charge for all students. Part of this reform includes the promotion of local wisdom and national arts and culture, and the development of the teaching profession. The result of this reform movement is the National Education Act B.E. 2542, which became effective in August 1999. The Act represents an unprecedented and long over-due break from traditional Thai educational norms. The Act also sets out to decentralize finance and administration and gives individual teachers and institutions more freedom to set curricula and mobilize resources. The principle objectives of the Act are to ensure that Thai education aims for the full development of people in all aspects: physical and mental health, intellect, knowledge, morality, integrity, and the pursuit of a desirable lifestyle in accordance with society and in harmony with other people. The year 2006 was declared as the Year of Teaching-Learning Reform by the Ministry of Education. The reform goals were to accelerate Thailand's transformation into a lifelong learning society, and to strengthen the capacities of its citizens in analytical thinking and self-learning, and to instill high moral values. The studies have been conducted on learning innovation, brain-based learning, provision of education for gifted children and youth, models for inculcation of moral and ethical values, integration of research into the learning process, and research and development studies of learner-centered models (OEC, 2006a). The reform has been concerned with the following three main areas (OEC, 2006c).

a) The reform of learning processes includes curriculum, instruction, evaluation and assessment and admission, and utilization of technologies for education.

b) The reform of teachers, faculty staff and educational personnel includes the reform of teacher production and teacher education institution, the development and promotion of teachers, faculty staff, and educational personnel, the professional standards development and control, and the reform of the personnel management of teachers, faculty staff and educational personnel.

c) The educational standards and the quality assurance system.

Some implications of this reform are that both teachers and students must change their roles. Teacher must change from a "teller" to a "facilitator", while learners must develop the capacities to learn by themselves. The Thai education system has long emphasized a "chalk and talk" pedagogy and rote learning, and has placed importance on school education with teachers as the center of teaching-learning activities. In addition, the knowledge was not relevant to the needs of learners and community (ONEC, 2000; Kaewdang, 2001). The Act also provides that the state should promote the running and establishment of all types of lifelong learning resources, such as public libraries, museums, art galleries, zoological gardens, and other sources of learning (Kaewdang, 2001; ONEC, 2002).

Section 24 of the 1999 National Education Act places emphasis on a student-centered approach (ONEC, 2003). Teaching and learning approaches that are learner-centered are the main approaches of education reform (ONEC, 1999). Learner-centered approaches are largely based on the constructivist learning theory. Constructivism has become a central epistemology in education (Tobin, Tippins, and Gallard, 1994) and this has implications for science education. Jean Piaget's account of children's learning as a process of personal, individual, intellectual construction arising from their activity in the world. Piaget believed that the individual constructs his or her own knowledge and meaning using two major principles to guide intellectual growth and biological development: adaptation and organization. Assimilation and accommodation are both part of the adaptation process. Piaget believed that human beings possess mental structures that assimilate external events, and convert them to fit their mental structures. Moreover, mental structures accommodate themselves to new, unusual, and constantly changing aspects of the external environment. The construction of knowledge is regarded of process of personal, individual, intellectual construction. Ernst von Glasserfeld (1993) argued that when people construct knowledge, their previous knowledge influences that construction. He proposed radical constructivism that denies transmitting knowledge from the person's mind to other minds. The radical constructivism assumes that learners can construct knowledge from their own experience and they can know about reality in a personal and subjective way (Topin and Tippins, 1993; von Glasersfeld, 1993). Then sociological constructivism is presented by a French sociologist. This sociological tradition maintains that scientific knowledge is socially constructed and vindicated and it investigates the circumstance and dynamics of science's construction. Therefore, based on the constructivism, learner-centered approaches emphasize that learners develop their own understanding of the different topics, and learning activities are prepared with regard to individual differences. The learners have opportunities to participate with peers, communities, and the environment and they can apply their knowledge to real life situations (ONEC, 2002).

With the view toward facilitating educational programs and teachers to organize the learning process, it is believed that teachers can choose the most appropriate situations to endow students with virtue, competence and happiness (ONEC, 2000). Therefore, teacher development is contained in the Thai teaching-learning reform in chapter 7 (section 52 – 57). This prescribes the development of teachers, faculty staff, and educational personnel with an emphasis on a paradigm shift in teacher development. The professional development is focused on the development of linkage between assessment of the teacher's professional competency and the learner's achievement (OEC, 2006a). In the next section, science education in Thailand is discussed including the goals of teaching and learning science and the science curriculum framework in Thailand.

Science Education in Thailand

The Eighth National Social and Economic Development Plan (1997-2002) aim Thailand that must become part of the nations of the world. Thai citizens should be prepared their education for the coming century. This plan emphasizes the development of human resources in science and technology. In addition, the ninth and tenth National Social and Economic Development Plans also adopt the philosophy of sufficiency economy as the guiding principle of national development and management. Therefore, the government of Thailand recognizes that these goals can only be achieved through the education system. The National Education Plan has stated that the primary goal is education that can develop all Thai citizens. The 1997 Constitution (Office of the Council of State, 2005) and 1999 National Education Act (Office of the National Education Commission [ONEC], 1999) lay an important foundation and play roles in Thai education reform. The National Education Act emphasizes the learning process that enhances Thai people in the following ways: to be aware of politics and a democratic system of government under a constitutional monarchy; to have the ability to protect and promote their rights, responsibilities, freedom, respect of the rule of law, equality, and human dignity; and to be proud of Thailand and promote its religion, art, national culture, sports, and local wisdom. The education provision shall be based on lifelong learning with a balanced orientation of knowledge, skill, and attitudes. The aim is for all learners to learn to be able to adjust to world trends and events, and to develop desirable characteristics including virtue, competency, happiness, and self-reliance (ONEC, 1999). In doing so, Thai education focuses on three types of education: formal, non-formal, and informal. Education shall be based on the principle that all learners are capable of learning and self development, and are regarded as being important. Many schools curricular respond to the educational reform and the King's philosophy developing teaching and learning process to reach the national education goal. The ninth National Social and Economic Development Plan emphasize that scientific and technological knowledge and skills should be integrated through formal, non-formal and informal education setting. Therefore, in 1999, the document was created by the Institute of Promotion of Science and Technology Teaching [IPST] that plays a major role in the teaching of science, mathematics and information technology in Thailand.

Globalization enhances Thai education that should realize the importance of science concept and the process of acquiring knowledge. In order to achieve science and technology goals, the science curriculum, the teaching and learning process, the assessment of student outcomes, and science teacher training need to change. A new science curriculum framework has also been formulated to help Thai people reach scientific literacy. The science curriculum framework has been prepared at two levels: national and institutional. At the national level, the science curriculum is one curriculum out of eight subject areas (Thai language, science, social studies, religion and culture, hygienic and physical education, arts, home economics and technology, and foreign languages) in the basic education curriculum (Ministry of Education, 2001). The national curriculum framework provides broad objectives, curricular strands, and standards for curricular content and learning outcomes, and assessment and evaluation methods of teaching and learning for science subjects (IPST, 2002).

Following the vision of science learning, IPST has incorporated the inquiry approach in teaching and learning science. Therefore, inquiry- based teaching and learning process is consisted into the aspects for developing of quality science teaching. According to the National Science Educational Standard [NSES], scientific inquiry refers to the methods and activities that lead to the development of scientific knowledge. Scientific inquiry that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 1996).

For a constructivist classroom, scientific inquiry involves learner-centered approach, with students actively engaged in inquiry processes and construction of meaning, with teacher guidance, to achieve meaningful understanding of scientifically accepted ideas targeted by the curriculum (Minstrell and van Zee, 2000). Moreover, inquiry approach is a set of scientist's processes and students pose questions about the natural world and investigate phenomena. Therefore, inquiry is more than asking questions. The meaning of inquiry in science education can vary as much as the methods of the scientific inquirer themselves. In addition, Bybee (2000) also described "science as inquiry" as comprising three main elements: (1) skills of scientific inquiry (what students should be able to do), (2) knowledge about scientific inquiry (what students should understand about the nature of scientific activity), and (3) a pedagogical approach for teaching science content. The first two elements are clearly articulated in the addendum to the NSES on inquiry (NRC, 2000).

Based on the National Science Education Standard (NRC, 1996a), inquiry is both a teaching approach and a learning goal. Inquiry goals include abilities to do inquiry and understanding about inquiry. The view of classroom inquiry is grounded in understandings of how science is practiced (Anderson, 2002). Anderson (2002) wrote that learning through inquiry mirrors authentic scientific practice in that the student researcher gathers information and data to answer questions in support of learning scientific principles. Relatively, Brown, Abell, Demir and Schmidt (2006) described inquiry as which refers to the diverse ways in which scientists study the natural world, propose ideas, and explain and justify assertions based upon evidence derived from scientific work. It also refers to more authentic ways in which learners can investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science.

The National Science Curriculum Standards (IPST, 2002) cover scientific inquiry in two parts. The first part is defined as the essence of scientific enterprise which is addressed in Substance 8: Nature of Science and Technology, as a core basic science that all students are expected to learn. It is explained in Standard Sc. 8.1: The student should be able to use the scientific process and scientific mind in investigation, solve problems, know that most natural phenomena have definite patterns explainable and verifiable within the limitations of data and instrumentation during the period of investigation, and understand that science, technology and environment are interrelated. Scientific inquiry plays a key role in guiding science teachers as a teaching and learning strategy and it should be used in teaching science.

In conclusion, the central meaning of scientific inquiry in the national education represents two critical aspects: 1) Inquiry as the essence of scientific enterprise, and 2) inquiry as a strategy for teaching and learning science. Both students and science teachers are expected to understand inquiry. Students in science classrooms can develop abilities that are essential to do scientific inquiry and can understand that scientific inquiry can be used to learn science concept. Students recognize that scientists use this approach to acquire scientific knowledge. Inquiry-oriented science instruction has been characterized in a variety of ways over the years and promoted from a variety of perspectives. Some have emphasized the active nature of student involvement, associating inquiry with "hands-on" learning and experiential or activity-based instruction. Others have linked inquiry with a discovery approach or with development of process skills associated with the scientific method.

In aspect of teaching and learning science in Thailand, scientific inquiry is an important approach that can engage Thai students to learn science and achieve scientific literacy. Scientific literacy is set to be a desirable characteristic in the National Science Curriculum Standards and is standard criteria for teaching and learning science. All learners are expected to be scientifically literate persons and the teaching and learning of science emphasizes the learner as the person doing the learning and discovering by him or herself so that process and knowledge are acquired from the pre-school years through education at the tertiary and post graduate level, and even at the work place. The formulation of science teaching and learning in school has the following aims for the learners (IPST, 2002):

a) To understand the principles and theories basic to science.

b) To understand the scope, limitations and nature of science.

c) To provide skills for discovery and creation in science and technology.

d) To develop the thinking process, imagination, ability to solve problems, data management, communication skills and ability to make decision.

e) To be aware of the relationships between science, technology, humans and the environment in terms of influence and impact on one another.

f) To utilize the knowledge and understanding of science and technology for the benefit of society and daily life.

g) To bestow the scientific mind, a moral and ethical sense of responsibility and proper values so that science and technology will be used constructively.

Under the National Education Act of 1999, education is decentralized and compulsory and has been extended from six years to nine years. Government-funded education, including science education, is available to all Thai citizens from year 1 through to year 12 and the curriculum framework provides eight strands, covering 12 years of basic education (Grade1-12) divided into four stages with each stage comprising three years. The subject groups specified are for core basic science which all students should learn. It consists of content, concept, principles and processes. At an institutional level, educational institution such as schools, are required to develop and implement their science curriculum and materials by themselves. Schools are encouraged to adapt the National Science Curriculum to be appropriate with their unique contexts. The curriculum should emphasize the needs of the society, local wisdom, and desirable attributes of members of the family, community, society, and nation. This type of curriculum is based on careful analysis of pupils' needs, abilities and interests, schools' ecological contexts, as well as the quality of teachers. Schools need to employ the most appropriate teaching, learning and assessment strategies and use diversified learning materials to integrate the teaching-learning-assessment cycle in their school-based curriculum.

Although, Thai schools have their own school-based curriculum, there are many issues in Thai education and the science curriculum framework. These issues include approaches to learning science, the use of instructional media and technology, and assessment and evaluation of student learning (IPST, 2002; Pillay, 2002). In particular, science teachers always interpret the curriculum framework with personal interjections and enact it differently because there are limitations such as class sizes, lack of science equipment and shortage of qualified teachers that effect science teaching and learning goals. Especially, teachers are important part of helping students develop scientific understandings, abilities, and dispositions. However, despite the importance of this role, many elementary teachers feel ill equipped and prepared to assume the task of engaging students in problem and inquiry-based approaches to teaching and learning science. This lack of preparation and confidence in teaching science would often translate into difficulty with teaching science; adopting conservative, low-risk approaches to teaching; and avoiding it altogether in the curriculum (Hilroyd and Harlen, 1995; Mulholland and Wallace, 2001; Appleton and Kindt, 2002). Therefore, teachers need appropriate knowledge that supports them to create their classrooms following school-based curriculum. The successful teachers should have a special knowledge that informs their teaching of particular content and that special knowledge is encapsulated in pedagogical content knowledge.

In the next section, pedagogical content knowledge is discussed including the purposes of PCK and its impact on science teacher education and student learning, the components of PCK and the definition of PCK used in this research.

Pedagogical Content Knowledge [PCK]

PCK as a Category within a Knowledge Base for Teaching

PCK is an important tool to identify what it means to be a good teacher and it represents teachers' understanding of difficult concept that students feel uncomfortable to learn, the selection of appropriate instructional materials, and pedagogy. The manner in which PCK is captured and represented is based on the view that this knowledge is important to recognize and acknowledge that there are many successful and effective ways for teaching particular science content. With increased attention on teachers' knowledge, PCK has become a central focus in learning how to teach (Geddis, 1993). Because PCK is specific to the teaching of particular topics and thus developed through an integrative process rooted in classroom practice (Van Driel, Beijaard, and Verloop, 2001). There are many research studies that are interested in PCK and their results presented that increasing PCK affects teachers' greater understanding of students' learning difficulties and misconceptions; teachers' use of appropriate content–specific teaching strategies and multiple modes of representation; and the enhancement of student learning (Clermont, Krajcik, and Borko, 1993; Tuan *et al*., 1995; Penso, 2002; van Driel, de Jong and Verlkoop, 2002; Zohar, 2004).

Teachers' knowledge influences what they know, what they think, and how they act in the classroom. Planning and teaching any subject is a highly complex cognitive activity in which the teacher must apply knowledge from multiple domains (Leindardt 1986; Resnick 1987; Wilson, Shuman and Richert, 1988; Borko and Putnam, 1996). Teachers who have differentiated and integrated knowledge will have more ability than those whose knowledge is limited and fragmented to plan and enact lessons that help students develop deep and integrated understandings. An effective teacher knows how to best design and guide learning experiences, under particular conditions and constraints to help diverse groups of students develop scientific knowledge and an understanding of the scientific enterprise (Mangnusson, Krajcik and Borko, 1999). While, teachers who have limited and fragmented content knowledge and have inappropriate PCK would be unable to create good classroom environments. They may provide inappropriate concept demonstrations, which may reinforce student misunderstandings (Clermont *et al*., 1994) and encourage rote learning that is a technique which avoids understanding of a subject and instead focuses on memorization. Teachers' knowledge is of pivotal importance in the design and conduct of teaching situations that may help students to learn science (Justi and van driel, 2005). Therefore, PCK is a reflection of what teachers know about students' learning and critical influences on encouraging students' learning in science subject (Zeegers, 2003). Much researches on science teachers' PCK proposes the understanding of subject matter acts as a prerequisite, preceding the development of PCK. Actually, subject matter knowledge is necessary but not sufficient for effective teaching. Teachers also need other knowledge that blends subject matter and pedagogy (Grossman, 1990; Ball and Bass, 2000).

Grossman (1990) to elaborate the knowledge bases of teaching, He suggested that possession of the knowledge described within PCK was anticipated as having the greatest impact on teachers' classroom actions. In this context, teachers' beliefs about teaching and learning have a pervasive influence on classroom practice (Appleton and Asoko, 1996). Attempts to articulate the critical links between practice and theoretical knowledge have proved to be exceptionally difficult. For many teachers, their practices and the knowledge, ideas, and theories that tend to influence that practice are often tacit (Loughran, Berry and Mulhall, 2007). The sources of differences between science teachers' various pedagogies can be tracked to the basic distinction between traditional transmissions of knowledge approach versus a reform oriented constructivist approach (Zohar, 2004). Most important is that the translation of subject-matter structures into classroom practice appeared to be complicated by classroom complexity. The validity of this assertion was supported by the numerous lines of research on teaching that has shown teachers' beliefs and knowledge are important factors on teachers' practice (Appleton and Asoko, 1996; Zohar, 2004; Loughran, Berry and Mulhall, 2007) and the importance of PCK in teachers' planning and actions when dealing with subject matter (Clermont, Krajcik, and Borko, 1993; Van Driel, Verloop, and De Vos, 1998), teachers' learning of new instructional strategies (Smith and Neale, 1989; Borko and Putnam, 1996; Zohar 2009), and student learning (Carpenter, Fennema, Peterson, and Carey, 1988; Penso, 2002).

Development of PCK leads teachers to have conceptual change and use effective teaching strategies and representation for science concept. Adams and Krockover (1997), who are interested in the development of beginning science teachers' PCK, propose that knowledge of instructional strategies was derived both from experiences as a learner and as a teacher or teaching assistant. Individual and contextual factors affect knowledge development. Smith and Neale (1989) study the effect of an in-service workshop which was a program for elementary teachers. This workshop focused upon the implementation of conceptual change strategies in science teaching. The researchers present that the program was particularly successful in the promotion of teachers' knowledge of specific content. Additionally, beliefs about the nature of science changed toward constructivist views. However, Smith and Neale report only marginal success with respect to the development of PCK. The participants are mainly constructing a deeply principled conceptual knowledge of content and their understandings about PCK as a prerequisite for the development of PCK.

Tsui and Treagust (2002) in a paper presented at the Australian Association for Research in Education [AARE] Conference in Brisbane, Australia, investigated that reflection upon teachers' practices can develop and improve teachers' pedagogical content knowledge. In addition, van Driel, Verloop, and de Vos (1998) investigated the effect of teacher's experience on PCK and they found that teaching experience was a major source of PCK, whereas adequate subject matter knowledge appeared to be a prerequisite. Teachers' PCK of participation in a workshop and conducting an experimental course in classroom practice reconstructed their PCK.

From these examples of research study, the development of PCK is an important on enhancing teachers' competency and students' learning. PCK is used as a guide of the design of science pre-service and in-service teacher education (e.g., Smith and Neale, 1989; Clermont, Krajcik, and Borko, 1993, 1994; Tuan *et al*., 1995; van Driel, de Jong and Verloop, 2002; Nolan and Goodnough, 2009).

Clermont, Krajcik, and Borko (1993, 1994) investigated chemistry teachers' PCK with a focus on their demonstrations as an instructional strategy. The second study compared PCK of experienced and novice demonstrators and the result shows that experienced teachers possess a greater repertoire of representations and strategies when demonstrations are more flexible for various purposes and they can relate their demonstrations more effectively to student learning than novices can. In the first study, they investigated the effects of PCK on an in-service workshop for novices. An intensive workshop was designed to help these teachers to develop their chemistry demonstration skills. After the workshop, most chemistry teachers could describe several alternative demonstrations related to density and air pressure concept that would be appropriate for a diverse group of middle school students. As growth of novices' PCK toward that their teaching practices were observed, the researchers concluded that PCK could be enhanced through intensive short-term, skill-oriented workshops (Clermont *et al*., 1993).

A growing body of empirical evidence suggests that teachers' subject-specific pedagogy (McDiarmid, Ball, and Anderson, 1989), otherwise known as pedagogical content knowledge [PCK], is limited (Feiman- Nemser and Buchmann, 1986; Buchmann, 1987; Wilson, Shulman, and Richert, 1988; Borko and Livingston, 1989; McDiarmid *et al*., 1989; McDiarmid, 1990; Borko and Putnam, 1996; Putnam and Borko, 1997). Teaching for understanding is a complex cognitive activity that requires the transformation of teacher knowledge from diverse domains (Wilson *et al*., 1988), including subject matter knowledge, general pedagogical knowledge, and knowledge of context [PCK] (Grossman, 1990). In addition, reaching to the reform's goals of science education science teachers are required knowing how to teach science in a different way from traditional teaching and integrating various teaching strategies with specific science concept. Importantly, the constructivist view is based on teaching and learning; therefore, science education programs need to revise to reach these reforms. Constructivist science teachers need to find out student alternative conceptions, help students to clarify and reflect on their own ideas, find content representations and materials to help students understand the concept, give them feedback, and find assessment to evaluate students' learning (Bell, 1993). Interestingly, PCK is the most important factor that encourages science teachers to create their classrooms based on the constructivist approach.

The Nature and Key Elements of PCK for Science Teaching

Since the 1980s, Lee Shulman's model of teacher knowledge incorporating the construct of pedagogical content knowledge has had an important impact on teacher education. There are several models and frameworks that have emerged to describe teachers' professional knowledge base for teaching. Shulman (1986) defined PCK as the amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding, and as a specific category of knowledge which goes beyond knowledge of subject matter to the dimension of subject matter knowledge for teaching. Beginning from 1983, Shulman outlined that within the category of pedagogical content knowledge has concluding 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, representing and formulating the subject that make it comprehensible to others, the most understanding of what make the learning of specific topics easy and difficult and the most knowing conceptions and preconceptions that students of different ages and backgrounds bring with them in classroom (Shulman, 1986). PCK was mentioned and described as an important factor of teachers' ability.

In 1987, Shulman's publication "Knowledge and teaching: foundations of the new reform" PCK was included in the knowledge base for teaching that consists of seven categories: (1) content knowledge, (2) general pedagogical knowledge, (3) curriculum knowledge, (4) PCK, (5) knowledge of learner and their characteristics, (6) knowledge of educational contexts, (7) knowledge of educational ends, purposes and values, and their philosophical and historical grounds.

Researchers in this area have used Shulman's characterization of PCK productively but have done little to clarify it (Marks, 1990). Shulman and others have proposed variants of model of the domains of teacher knowledge (for example, Tamir, 1988; Carlsen, 1999; Magnusson, Krajcik, and Borko, 1999). The definitions of the components within the different models vary. Ball (1988) used the same basic assumption and she explored the more dynamic aspect of this idea, examining pre-service teachers' pedagogical reasoning in mathematics as the process whereby they build their knowledge of teaching and learning. Some groups of researchers investigated teachers' knowledge and they accepted Shulman's definition, adding a distinction between pedagogical content knowledge and pedagogical content beliefs (Carpenter, Fennema, Peterson, and Carey, 1988; Peterson, Fennema, Carpenter, and Loef, 1987). Their research focused on a small number of specific knowledge measure emphasizing teacher's awareness of how their students learn. Therefore, Grossman (1990) has tried to remedy these various models and conceptions by distinguishing four general areas of teacher knowledge including general pedagogical knowledge; subject matter knowledge; PCK; knowledge of context. This model, PCK is presented as a unique knowledge domain (See also Figure 2.)

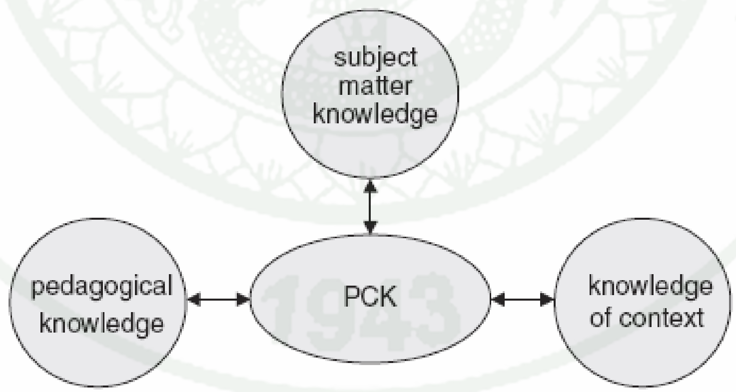

Figure 2.1 The Model of Teacher Knowledge

Source: Grossman (1990)

Grossman explained knowledge base for teaching that consists of general knowledge that is defined as knowledge concerning learning and learners, knowledge of general principles of instructions, knowledge related to classroom management, and knowledge about the aims and purposes of education. Knowledge of context includes knowledge about school setting; for example, culture and knowledge of individual students. The PCK of Shulman still has one unclear aspect since there seems to be no distinction between PCK as an educational concept, an abstract idea used in teacher education and textbooks, and PCK as a subjective representation.

PCK has been adapted and reconceptualized by many authors and Shulman's notion of PCK has been interpreted in many different ways (Grossman, 1990; Geddis *et al*., 1993). Some educators have argued against Shulman's conceptualization of PCK (e.g., McEwan and Bell. 1991; Cochran, DeRuiter, and King, 1993; Meredith, 1995). For example, McEwan and Bull (1991) argue that it is not necessary to make a distinction between content knowledge and PCK because "all content knowledge whether held by scholars or teachers, has a pedagogical dimension" (p.318). McEwan and Bull also argue that Shulman's conceptualization would be more acceptable if there were philosophical perspectives supporting it. Cochran, DeRuiter, and King (1993) argued that PCK is static and is not consistent with a constructivist based view. Therefore, they revised Shulman's original model to be more consistent with a constructivist perspective on teaching and learning. They described a model of pedagogical content knowledge that results from an integration of four major components, two of which are subject matter knowledge and pedagogical knowledge. The other two other components of teacher knowledge also differentiate teachers from subject matter experts. One component is teachers' knowledge of students' abilities and learning strategies, ages and developmental levels, attitudes, motivations, and prior knowledge of the concept to be taught. Students' prior knowledge has been especially visible in the last decade due to literally hundreds of studies on student misconceptions in science and mathematics. The other component of teacher knowledge that contributes to pedagogical content knowledge is teachers' understanding of the social, political, cultural, and physical environments in which students are asked to learn. The PCK model shows that these four components of teachers' knowledge all contribute to the integrated understanding that we call pedagogical content knowledge; and it indicates that pedagogical content knowledge continues to grow with teaching experience. Cochran *et al*. (1993) added the environmental context of learning into the discussion of PCK. However, most researchers still refer to Shulman's conceptualization in their research developments (e.g., Grossman, 1989; Mark, 1990; Goddis *et al*., 1993; Magnusson, *et al*., 1999; Veal and MaKinster, 1999; Dijk and Kattmann, 2007; Dijk, 2009). Various conceptualizations of PCK component are built and used to explain that knowledge is crucial to enhance teachers promoting meaningful learning to their students.

Several science education researchers have suggested modifications to earlier PCK models. A summary of components in different conceptualizations of PCK is proposed in Table 2.1 Based on research evidences, Tamir (1988), for example, proposed knowledge and skills of assessment as another dimension of PCK. Carlsen (1999) reiterated the importance of the inclusion of understanding student misconceptions as a component of the PCK model for science teaching. In addition, this knowledge is critical to understand effective science teaching (Magnusson, Krajcik and Borko, 1999) Therefore, PCK is one important knowledge domain that focuses on learning to teach about a new paradigm. The concept of PCK refers to teacher‘s interpretations and transformations of subject-matter knowledge in the context of facilitating student learning (van Driel, Verloop and de Vos, 1998).

Table 2.1 Knowledge Components in Different Conceptualizations of PCK

	Knowledge of						
Scholars	**Beliefs and Orientation to Teaching**	**Student Learning and Conceptions**	**Representations and Teaching Strategies**	**Curriculum and Materials**	**Assessment**	**Context**	**Subject matter**
Shulman (1986)		PCK	PCK				
Shulman (1987)	PCK	PCK	PCK				
Grossman (1989)	PCK	PCK	PCK	PCK			
Marks (1990)		PCK	PCK	PCK			PCK
Cochran *et al*.(1993)		PCK	PCK			PCK	PCK
Geddis *et al*. (1993)		PCK	PCK	PCK			
Fernandez-Balboa and Stiehl (1995)	PCK	PCK	PCK			PCK	PCK
Magnusson *et al*.(1999)	PCK	PCK	PCK	PCK	PCK		

The integrated nature of pedagogical content knowledge is also described by Kennedy (1990). A teacher's PCK is shaped by context and experience, but an important aspect that is PCK is a cornerstone of a teacher's professional expertise. Because of PCK would be that few teachers are able to articulate their PCK publicly for others. Regardless of its interpretation, there are few concrete examples of PCK in subject areas. Van Driel, Verloop, and De Vos (1998) highlighted this as a concern when they noted that although the research community embraced the notion of PCK, few science specific examples are cited in the literature to illuminate this important aspect of teachers' professional knowledge.

Magnusson, Krajick and Borko (1999) modified Grossman's model and this idea is depicted graphically in Figure 2.2 which presents a model of the relationships among the domain of teacher knowledge. The shaded boxes are the major domains of knowledge for teaching. The lines that link the domains of knowledge illustrate the relationship between pedagogical content knowledge and the other domains of knowledge for teaching. The figure is intended to depict that pedagogical content knowledge is the result of a transformation of knowledge of subject matter, pedagogy and context, but the resulting knowledge can have an effect on the development of the base knowledge domains in turn. The PCK model of Magnusson and his colleague has been described as the transformation of several types of knowledge for teaching. These types of knowledge include subject matter knowledge, pedagogical knowledge (classroom management, educational aims), and knowledge about context (school, students) (Magnusson, Krajcik, and Borko, 1999).

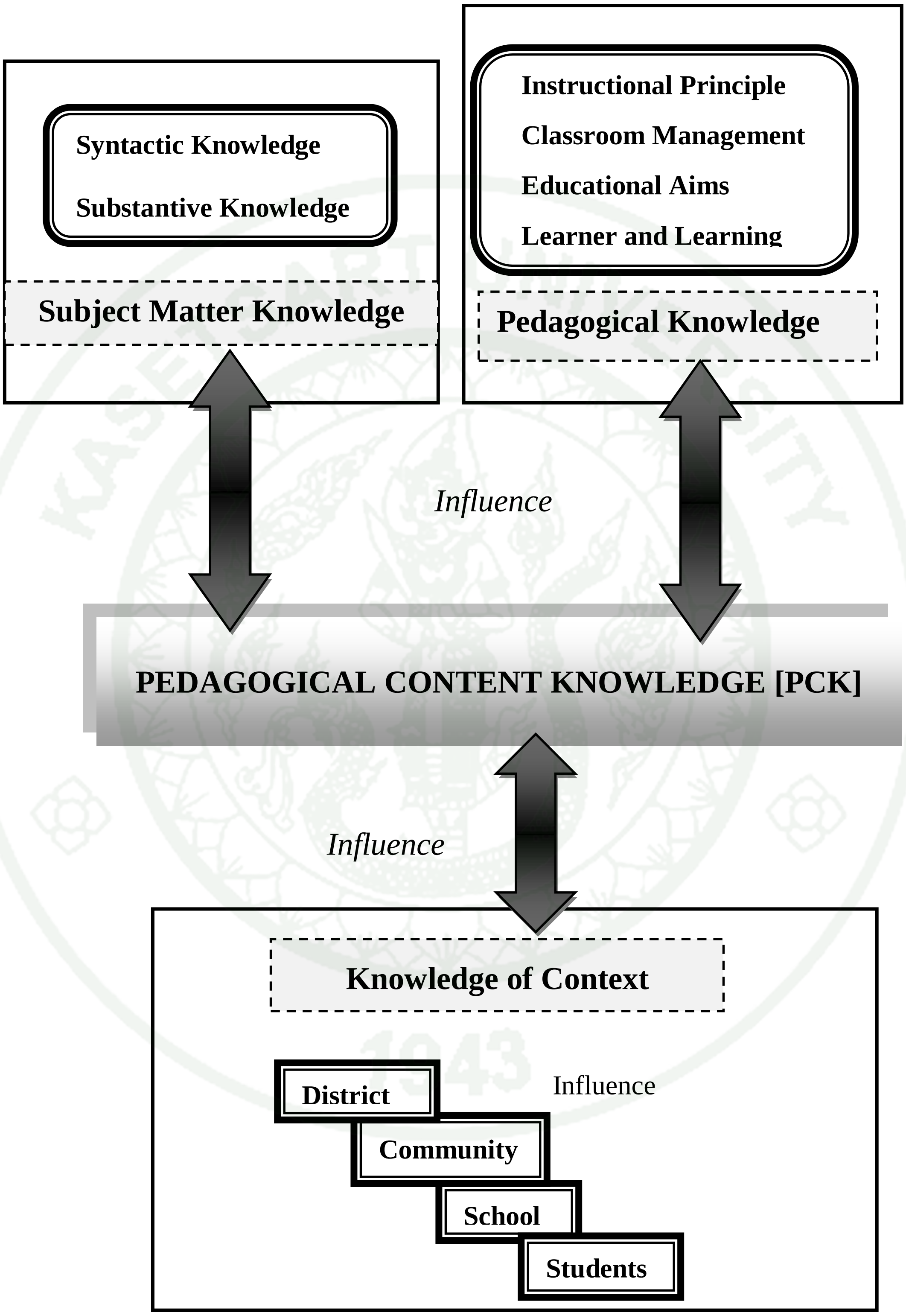

Figure 2.2 A Model of the Relationships among the Domains of Teacher Knowledge

Source: Grossman (1990) and Magnusson, Krajcik and Borko (1999)

Within the literature on PCK for science teaching, knowledge and beliefs are often combined (Gess-Newsome and Lederman, 1999; Veal, 2004; Friedrichsen and Dana, 2005). Therefore, pedagogical content knowledge has been described as "the transformation of several types of knowledge for teaching" (Magnusson, Krajcik, and Borko, 1999.). These types of knowledge include subject matter knowledge, pedagogical knowledge (classroom management, educational aims), and knowledge about context (school, students). Some research has also studied both teacher knowledge and their practice (Veal, 2004 and Brown and Melear, 2006).

General PCK is the first level within this taxonomy. General PCK is more specific than pedagogy, because the concept and strategies employed are specific to the disciplines of Science, Art, History, Math, or English. Magnusson, Krajcik, and Borko (1999) called subject-specific PCK strategies as general PCK. Domain-specific PCK focuses one of the different domains or subject matters within a particular discipline. Domain-specific PCK is positioned between disciplines and domains of science to represent a different level and specificity of subject-matter and pedagogy Both activities involve the laboratory within the disciplines of science, but the individual tools and purpose are specific to the subject matter or domain. The most specific and novel level of the general taxonomy is topic -specific PCK. Theoretically, a teacher who has knowledge in this level of PCK could have a solid repertoire of skills and abilities in the previous three levels. Each domain or subject of science has its own list of concept, terms, and topics, some of which overlap (e.g., Magnusson and Krajcik, 1993). Although the concept unique to each domain may be taught differently, the common concept is also taught differently on many occasions.

For science teaching, teacher knowledge of helping students better understand science and prepare them for future learning both within and outside of the educational system is seen as topic-specific PCK. Science teachers need to know, not only how to teach science but also how to teach particular topics with an appropriate strategy to a particular group of students (Van Driel *et al.*, 1998). This means that teachers should have topic-specific PCK. Science teaching and learning should be interested in knowledge integration that involves applying this knowledge integration processes to ideas such as scientific principles, real-world experiences, and classroom-based experiences to develop robust and usable understandings (Davis, 2003; Linn and Eylon, 1996). Therefore, development of science teacher pedagogical content knowledge is important to help students learning of scientific concept.

A Model of PCK for Elementary Science Teachers

Building upon the work of Grossman (1990), Shuman (1986), and Magnusson *et al*. (1999), this study focuses on combining teacher knowledge, belief, and practice into the PCK model. PCK is a unique domain that is informed by the other knowledge areas. The foundational knowledge domains, subject matter, pedagogy, and context, inform PCK and PCK influences the teachers' knowledge (Gess-Newsome, 1999). Magnusson and his colleagues presented a PCK model for teaching science which is appropriate for adjusting and modifying to a model for teaching science at the elementary level. This model has been modified for use in the current study. The discussion and justification of this PCK model focuses on teaching science (general), biology, physics, chemistry, mathematics, or geology (domain-specific), and science topics (topic-specific), and overlaps between these specific levels of PCK.

The PCK model for teaching science of the study, the researcher defines PCK as a knowledge domain that consists of a combination of subject matter knowledge and beliefs, pedagogical knowledge and beliefs, and knowledge and beliefs about context. This study, PCK for science teaching is conceptualized as a blend of content knowledge into pedagogical knowledge for application these knowledge realizing on context to enables them to transform particular content knowledge into form that is understandable for diverse group of students. Effective science teachers can integrate appropriated strategies into specific content knowledge. Therefore, when they transform their content knowledge to students, the teachers will present their understanding or conception of that science topic. Pedagogical knowledge focuses on knowledge and beliefs about the purposes and goals for teaching science, knowledge and beliefs about curriculum, knowledge and beliefs about assessment in science, knowledge of instructional strategy for teaching science, and knowledge and beliefs about learner and learning. Knowledge and beliefs about context includes context of community, school, district and students. This component of PCK has to integrate into blending other components of PCK. Science teachers have to understand their context and select useful form of representation to transform their knowledge to students. In aspect of context of students, it focuses on knowledge and beliefs about students' alternative conceptions, student learning in science, and requirements for learning.

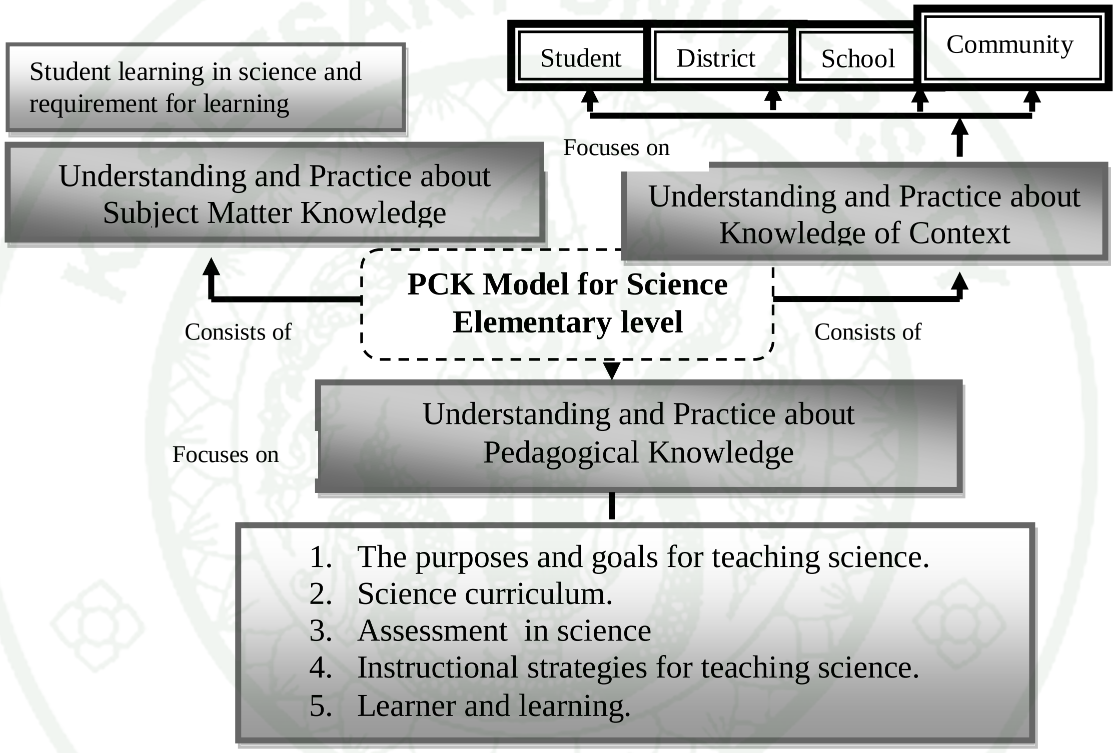

Figure 2.3 A Model of the Relationships among the Domains of PCK of the Research Study

Source: Grossman (1990) and Magnusson *et al.* (1999).

Each component of PCK model has its own sub-topics that are important to enhance science teachers to develop their knowledge. Each component complexly interacts and functions as parts of PCK. All these components should be simultaneously developed and integrated to become PCK. The integration of knowledge components reflects how science elementary teachers have their knowledge and use it into their practices. The PCK model of the research is depicted graphically in Figure 2.3. Science teachers need to develop all of these components of PCK. PCK is not only one aspect of knowledge but is integrated knowledge. The details for each knowledge component of PCK are described in the following paragraphs.

1. Understanding and Practice about Subject Matter Knowledge

Shulman (1986) introduced pedagogical content knowledge [PCK] and sparked a new wave of scholarly articles on teachers' knowledge of their subject matter and the importance of this knowledge for successful teaching. One component of PCK of Schulman’s definition is teachers' subject-matter knowledge. To teach all students according to today’s standards, teachers need to understand subject matter deeply and flexibly so they can help students create useful cognitive maps, relate one idea to another, and address misconceptions. Teachers need to see how ideas connect across fields and to everyday life. This kind of understanding provides a foundation for pedagogical content knowledge that enables teachers to make ideas accessible to others (Shulman, 1987).

Especially important is content knowledge that deals with the teaching process, including the most useful forms of representing and communicating content and how students learn the specific concept and topics of a subject. Teacher subject matter knowledge is defined in quantitative terms by the number of courses taken in college or teachers' scores on standardized tests (Wilson, Shulman, and Richert, 1987; Ball, 1991). But these "measures" are problematic, since they do not represent teachers' knowledge of the subject matter. In recent years, teachers' subject matter knowledge has been analyzed and approached more qualitatively, emphasizing knowledge and understanding of facts, concept, and principles and the ways in which they are organized, as well as knowledge about the discipline; that is, ways to establish truth (Leinhardt and Smith, 1985; Shulman, 1986; Tamir, 1987; Wilson *et al*., 1987; Ball, 1988, 1991; Even, 1990; Kennedy, 1990). Another category of subject matter knowledge of teachers that has gained greater attention in recent years is pedagogical content knowledge. This kind of knowledge is described as knowing the ways of representing and formulating the subject matter that makes it comprehensible (Even, 1993). Teachers' experiences influence pedagogical content knowledge. Exposure to relevant developmental and cognitive research, including learning theories, and interactions with students, are other factors. Another source of pedagogical content knowledge is the nature and depth of teachers' own subject-matter knowledge. Science teachers have to know what strategy they should use to help students learning in specific scientific topics. Therefore, subject matter knowledge is crucial for integrating into this PCK model.

Strong subject matter knowledge is necessary but not sufficient for effective teaching. Teachers also need knowledge that blends subject matter and pedagogy (Ball and Bass, 2000; Grossman, 1990). Therefore, aspects of teachers' subject matter knowledge considered as PCK components include what teachers understand about the scientific concept in topics that they integrate with appropriate instructional strategies. This subject matter knowledge relates with the scientific knowledge that is taught at the elementary school level. Science elementary teachers are expected to have subject matter knowledge that is consistent with scientific knowledge and they can transform this knowledge to their students through effective instructional strategies. Students are encouraged to understand scientific conceptions. The goal of teaching is to facilitate students to construct their own science concept, develop science process skills, gain positive attitudes towards science and scientific attitudes, and apply these aspects in students' daily lives. Science can be knowledge such as, principles, laws, and theories that explain the world around us and it is inquiring for knowledge. Based on constructivist-based views of learning, students are seen as active learners who can construct their own knowledge while teachers are regarded as facilitators who provide learning activities for students

2. Understanding and Practice about Pedagogical Knowledge

2.1 Knowledge and Beliefs about the Purposes and Goals for Teaching Science

This component of pedagogical content knowledge refers to teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level. Some educators have used the terms knowledge and beliefs interchangeably (Van Driel, Beijaard, and Verloop, 2001). In this study, teachers' knowledge is seen as an important component of knowledge for teaching particular subjects. Grossman (1989) designated this component as consisting of knowledge of the purposes for teaching a subject at a particular grade level or the overarching conceptions of teaching a particular subject. Grossman's (1990) model used the descriptive phrase "conceptions of purpose for teaching subject matter" (p.8) rather than orientations. In the Magnusson *et al*., (1999) PCK model, orientations to teaching science is placed in a pivotal position of Grossman's model. Research in science education has referred to this component as "orientations toward science teaching and learning," (Anderson and Smith, 1987; Dana and Friedrichsen, 2005). Anderson and Smith (1987) described teachers' orientations toward science teaching and learning as general patterns of thought and behaviour relating to science teaching and learning. An orientation represents a general way of viewing or conceptualizing science teaching. The significance of this component is that these knowledge and beliefs serve as a conceptual map that guides instructional decisions about issues such as daily objectives, the content of student assignments, the use of textbooks and other curricular materials, and the evaluation of student learning (Borko and Putnam.1996). Magnusson *et al*. (1999) argued that an orientation represents a general way of viewing or conceptualized according to the characteristics of the instruction.

The orientations are generally organized according to the emphasis of the instruction from purely process or content to those that emphasize both and fit the Thai national standard of being inquiry-based. Each orientation has then been described with respect to two elements that are useful in defining and differentiating them: the goals of teaching science that a teacher with a particular orientation would have, and the typical characteristics of the instruction that would be conducted by a teacher with a particular orientation. Magnusson *et al*. (1999) identified nine different science teaching orientations: (1) process, (2) academic rigor, (3) didactic, (4) conceptual change, (5) activity-driven, (6) discovery, (7) project-base science, (8) inquiry, and (9) guided inquiry. A comparison of the characteristics of instruction that follow from particular orientations reveals that some teaching strategies, such as the use of investigations, are characteristic of more than one orientation.

This similarity indicates that it is not the use of a particular strategy but the purpose of employing it that distinguishes a teacher's orientation to teaching science. For example, teachers with a discovery, conceptual change, or guided inquiry orientation each choose to have students investigate series and parallel circuits, but their planning and enactment of teaching relative to that goal would differ. The teacher with a "discovery" orientation will give students with experimental materials such as batteries, bulbs, and wires, and proceed by having them follow their own ideas as the students find out what they can make happen with the materials. The students are expected to discover that there are different types of circuits. The purpose of the instructional activity would be for students to discover what they can about electrical phenomena through pursuing their own questions. This purpose is different from a teacher who has a "conceptual change" orientation and he or she will begin by encouraging students to talk about their ideas about electricity to have them become aware of their own ideas and differences between their ideas and others. The teacher will know some of the misconceptions they have about electricity. Both teachers' orientations that are mentioned will be different from the teacher who has a "guided inquiry" orientation. The teachers will begin by engaging their class in the task to establish a question or problem related to exploring electricity. Students will investigate their ideas and report the result their ideas about the behaviour of electricity to the class during each cycle of exploration so that, as a learning community, they could determine the best ideas to go forward with to proceed to the next cycle of investigation.

These examples illustrate the central role of this component of PCK in decision-making relative to planning, enacting, and reflecting upon teaching. Many researches indicated that teachers' orientation and teachers' practice in classroom would be related. Some science educators argue that teachers' beliefs about the nature, teaching and learning of science also interact with teachers' knowledge

(Hewson and Hewson, 1989; Cronin-Jones, 1991; Leaderman *et al*., 2002). Veal (2004) found that teacher beliefs about teaching are related to content knowledge, knowledge of students, and the nature of subject. Teachers' beliefs influence the construction of their views of content knowledge, the use of representations, the integration of their knowledge of students, and the influence of the context on their teaching practice.

Many researchers investigate teachers' beliefs about goals or purpose for teaching science (Grossman, 1989; Hewson and Hewson, 1989; Friedrichsen and Dana, 2003; 2005); student learning of science; role and characteristics of students; teacher teaching of science; and teacher roles and characteristics (Hewson and Hewson, 1989; Aquirre *et al*., 1990; Prawat, 1992; Pomeroy, 1993; Bryan and Abell, 1999; Koballa *et al*., 2000; Haney and McArthur, 2002; Bryan, 2003). This research has a common result and demonstrates that teachers realize teaching and learning science is based on the constructivist view. For example, Levitt (2002) found that teachers believe the learning of science should be personally meaningful to students and students are active participants in learning science and should engage in Hand-on activities. Therefore, the teachers feel that the best way of teaching and learning of science is with s student–centered approach. Different from other research that has proposed teachers who believe in teacher-centered approach, teachers acted as a deliverer of knowledge and the student as a receiver of knowledge (Aquirre *et al*., 1990; Lemberker *et al*., 1999; Koballa *et al*., 2000; Veal and Kubasko, 2003). Teachers' beliefs about the nature, teaching, and learning of science have relationships with teachers' teaching practice (e.g. Cronin-Jones, 1991; Powell, 1994; Appleton and Asoko, 1996; Lemberker *et al*., 1999; Veal, 2004). Teachers' beliefs can be viewed as a conceptual map used to develop and enact specific teaching and learning activities and they also are seen as a referent which organizes their knowledge (Tobin *et al*., 1996; Zembal-Sual *et al*., 1999). In other worlds, teacher's beliefs influence instructional decisions about class goals and objectives, curriculum materials, activities and assignments for students, and evaluation of student learning (Cronin-Jones, 1991; Appleton and Asoko, 1996; Borko and Putnam, 1996). Veal (2004) presents that "beliefs informed the practice of the participants in the classroom and knowledge gained in the classroom informed the participants' beliefs" (p. 346). Hashweh (1996) proposed that primary and secondary science teachers' epistemological beliefs are strongly correlated with their teaching practice. Teachers who have constructivist beliefs are more likely to detect student alternative conceptions; have a richer repertoire of teaching strategies; use potentially more effective teaching strategies; and highly value these teaching strategies compared views of teaching and learning, they will try to transmit knowledge directly to students (De Jong *et al*., 1999).

In summary, teachers' purposes and goals of science teaching and learning are considered as a sub-component of PCK. They are related to knowledge of instructional strategies including: (1) overall of purposes and goals for teaching science, (2) student learning of science, (3) roles and characteristics of students, (4) teacher teaching of science, and (5) roles and characteristics of teachers. Science elementary teachers are expected to hold constructivist beliefs: the goal of teaching is to facilitate students to construct their own science concept, develop science process skills, gain positive attitudes toward science and scientific attitudes, and principles, laws, and theories that explain the world around them and it is inquiring for knowledge. Students will act as active learners and teachers will be their facilitators who encourage student to construct their own knowledge.

2.2 Knowledge and Beliefs about Science Curriculum

Shulman and colleagues originally considered curricular knowledge to be a separate domain of the knowledge base for teaching (Wilson, Shulman, and Richert, 1988). Shulman proposed the "curricular alternatives" and he argues that teachers should have an understanding about curricular alternative for teaching. The curricular alternatives require teachers to know materials or tools of teaching that present and exemplify particular content or evaluate student knowledge. Therefore, knowledge of curriculum is integrated as component of PCK by leading Grossman (1990) who included knowledge of science curriculum into as one part of pedagogical content knowledge because it represents knowledge that distinguishes the content specialist from the pedagogue a hallmark of pedagogical content knowledge. The knowledge component of PCK comprises two categories: specific curricular materials; and, mandated goals and objectives. The first category, knowledge of specific curricular materials, refers to an understanding about various types of curricular, such as curriculum documents (both national and school based), teaching manuals, textbooks, laboratory materials, instructional media, and so forth. The second category involves teachers' understanding of goals and objective in the topic they are teaching at a specific grade level as proposed in the Science Curriculum Framework in both horizontal and vertical manners. This category of the curricular knowledge component of pedagogical content knowledge includes teachers' knowledge of the goals and objectives for students in the subjects they are teaching, as well as the articulation of those guidelines across topics addressed during the school year. It also includes the knowledge teachers have about the vertical curriculum in their subjects; that is, what students have learned in previous years and what they are expected to learn in later years (Grossman, 1990). Examples of sources for knowledge of goals and objectives include national or state-level documents that outline frameworks for guiding decision-making with respect to science curriculum and instruction (e.g., AAAS, 1989; Michigan State Board of Education, 1991). Schools and districts may also have documents that indicate, for specific courses or programs, what concept are to be addressed to meet mandated goals. Effective science teachers are knowledgeable about these documents. Teachers' knowledge of curricula such as these would include knowledge of the general learning goals of the curriculum as well as the activities and materials to be used in meeting those goals.

Several studies that provide a picture of the general state of science education (e.g., Helgeson, Blosser and Howe, 1977; Stake and Easley, 1978; Weiss, 1978, 1987) have reported that the vast majority of teachers surveyed were not knowledgeable about nationally-funded curriculum projects relevant to their teaching. Teachers are expected to be aware of what is highlight in the curriculum as valuable for teaching particular subjects (Peterson and Treagust, 1998; Jones and Moreland, 2003; Laughran *et al*., 2004). As a result, there are typically several programs at each grade level and for each subject area, about which teachers should be knowledgeable.

There is also evidence that teachers who are knowledgeable about programs may not agree with their learning goals and as a result may substantially modify them or reject important parts of materials (Cronin-Jones, 1991; Mitchener and Anderson, 1989; Welch, 1981). Moreover, teachers also need to know the sequence or relationship between topics, which can help them, set and design learning activities for their students. This finding provides some evidence of the issue of coherence with respect to the components of PCK, in this case the lack of coherence of teachers' orientations toward science teaching and the focus of the curricular materials. Understanding of mandated goals and objectives in the curriculum encourages teachers to know how to teach science subject with appropriate time and content. The teachers will know how to create a science classroom that covers the curriculum and how to teach students to have understanding.

2.3 Knowledge and Beliefs of Assessment in Science

Assessment is at the heart of the student experience. As Brown (1997) said;

> …Assessment defines what students regard as important, how they spend their time and how they come to see themselves as students and then as graduates...If you want to change student learning then change the methods of assessment.

There are a variety of purposes in an educational setting used to assess data. They are: to gather evidence of student learning; assist learning; guide teaching; measure individual achievement; give grades; allocate resources; evaluate programs; and inform local, state, and national policy. Used for these purposes, assessment tells teachers how students are learning; how to improve education; and how to give feedback to students, educator, parents, policymakers, and the general public about how students are doing in science (Pellegrino, Chudowsky, and Glaser, 2001). Knowledge of this component of pedagogical content knowledge, which was originally proposed by Tamir (1988) who suggested the knowledge of assessment in science, consists of two categories of knowledge. Knowledge of the dimensions of science learning that are important to assess, and knowledge of the methods by which that learning can be assessed. The knowledge of dimensions of student learning refers to what teachers know about aspects of student learning and can frame teachers' decision-making related to lesson planning, classroom activities and the assessment methods in student learning, For example, in teaching and learning science, science process skills, and attitudes towards science and scientific attitudes, are key aspects of student learning (Erdura and Scerri, 2002).

The knowledge of dimensions of science learning to assess refers to teachers' knowledge of the aspects of students' learning that are important to assess within a particular unit of study. Enhancing student's scientific literacy is a major goal of school science for developing citizenry (Hurd, 1989). This is similar to the National Education Act of Thailand which is the country's master legislation on education which will provide the framework for education reform. Therefore, Thailand needs to improve some of the education systems to prepare people for an increasingly global era. The National Science Curriculum Standards (IPST, 2002), the visions for science learning in compliance with Basic Education Curriculum realizes the need to foster students to be scientific literate. That means that it is important for teachers to be knowledgeable about some conceptualization of scientific literacy to inform their decision-making relative to classroom assessment of science learning for specific topics. Thus, effective teachers should know what dimensions or aspect of a dimension of scientific literacy should be assessed in a particular unit. They should plan to assess students' understandings regarding the planning and conduct of empirical investigations during the study of weather by having them actually carry out investigations, and they should plan to utilize a different method of assessment during the study of the science topic. Therefore, the other category of teacher knowledge of assessment: knowledge of methods of assessment is integrated in the knowledge of assessment in science.

The knowledge of method of assessment refers to teachers' knowledge of the ways or strategies that might be employed to assess the specific aspects of student learning that are important to a particular unit of study. There are a number of methods of assessment, used to assess student learning, depending on activities or lesson in science classroom, some of which are more appropriate for assessing some aspects of student learning than others. For example, students' conceptual understanding may be adequately assessed by written tests or concept maps whereas their understanding of scientific investigation may require assessment through a laboratory practical examination (e.g., Lunetta, Hofstein, and Giddings, 1981; Tamir, 1974) or laboratory notebooks. Other strategies to assess student learning are journal writing, surveys, laboratory report, and portfolios. Student learning should assess not only at the end of activities, but during the time of activities. Students should be assessed of their learning and achievement during the process of teaching and learning specific content (Jones and Moreland, 2003).

For science education, attention to assessment practices and the development of new methods such as performance-based assessments and portfolios is changing (e.g., Duschl and Gitomer, 1991; Kulm and Malcom, 1991). Performance assessment reflects the growing consensus among educators about the impact of evaluation on what students learn and what teachers teach (Moss, 1992). These methods highlight that student-generated products provide important opportunities for assessment, whether evaluated at the end of a unit of study or during the course of study. Typically, students are permitted substantial latitude in interpreting, responding to, and perhaps designing tasks; they result in fewer independent responses, each of which is complex, reflecting integration of multiple skills and knowledge; and they require expert judgment for evaluation. Teachers can use various alternative ways to explore, monitor and develop students' thinking. For example, student-generated products that have been used to assess student learning include journal entries, written laboratory reports, and artifacts such as drawings, models, or multi-media documents (Magnusson, Krajcik and Borko, 1999).

Therefore, teachers' knowledge of methods of assessment focuses on knowledge of specific instruments or procedures, approaches or activities that can be used during a particular unit of study to assess important dimensions of science learning, and the advantages and disadvantages associated with using a particular assessment device or technique. Research examining teachers' use of assessment and the results indicates that teachers largely depend upon teacher-constructed or curriculum-embedded objective tests that evaluate the conceptual understanding dimension of scientific literacy (Doran, Lawrenz Helgeson, 1994). Most research does not indicate the influence on teacher practice from a lack of knowledge of other methods, a lack of knowledge of the need to evaluate other dimensions of scientific literacy, or other issues. As efforts to integrate scientific literacy at all grade levels continue and as new instruments and procedures continue to be developed and become more prominent in this "decade of reform in student assessment" in science education (Tamir, 1993, p. 535), pedagogical content knowledge in this area is likely to change substantially. Assessment of teaching and learning science is a crucial aspect of PCK, and science teachers should have appropriate knowledge so they can integrate this type of knowledge with other components of PCK.

2.4 Knowledge and Beliefs about Instructional Strategies

Knowledge of instructional strategies is an important component of the PCK model. This knowledge domain focuses on knowledge of subject-specific strategies and topic-specific strategies. Subject-specific strategies are broadly applicable; they are specific to teaching science as opposed to other subjects. Topic-specific strategies are much narrower in scope; they apply to teaching particular topics within a domain of science.

Knowledge of subject-specific strategies included in this category represents general approaches to or overall schemes for enacting science instruction. Teachers' knowledge of subject-specific strategies is related to the orientations to teaching science component of pedagogical content knowledge in that there are general approaches to science instruction that are consistent with the goals of particular orientations. In science education, many subject-specific strategies have been developed, in a three- or four- phase instructional sequence. Science elementary teachers should understand and implement constructivist-based teaching strategies;

for example, the Conceptual Change Model (Posner *et al*., 1982), the Interactive Teaching Approach (Biddulph and Osborne, 1982), the Generative Learning Model (Cosgrove and Biddulph and Osborne, 1984), the Focus-Action-Reflection Guide teaching approach (Treagust, Harrison and Venvile, 1998) and the 5E learning Cycle (Bybee, 1997). The most popular strategy is the learning cycle consisting of a three-phase instructional strategy; exploration, term introduction, and concept application (Karplus and Thier, 1967; Lawson, Abraham, and Renner, 1989). This strategy has been used for discovery and inquiry-oriented instruction, as well as conceptual change-oriented instruction (Tobin, Tippins, and Gallard, 1994). The learning cycle is used to develop many teaching strategies for science. Recently, strategies have typically added phases designed to support conceptual change, such as exploring students' prior knowledge (Osborne and Freyberg, 1985), presenting anomalous data to create cognitive conflict, proposing children have firmly held conceptions based on their everyday experiences and the common use of language, (e.g., Nussbaum and Novick, 1982), distinguishing between real world patterns that can be discovered and explanations for them that must be invented (e.g., Magnusson and Palinesar, 1995), emphasizing public presentation and discussion of patterns and explanations or scaffolding student debate about the adequacy of alternative explanations (e.g., Anderson and Smith, 1987). These teaching strategies are based on the constructivist-based view of teaching and learning which tend to focus on student prior knowledge or alternative conceptions as the heart of teaching planning. The ways of identifying and eliciting students' prior knowledge or alternative conceptions and learning difficulty are crucial considerations for teachers' decision making of their instructional plan. Moreover, students' interest is also another point that teachers should realize and integrate with teachers' teaching. Teachers invite students to clarify questions for investigating what they are interested in and students have the chance to discuss and share their findings with others, and evaluate their own learning about the topic. The classroom environment is democratic, the activities are interactive and student centered, and the students are empowered by a teacher who operates as a facilitator or consultant.

Teachers who have effective subject-specific strategies would not mean that they are good in science teaching because a teacher's ability to use a subject-specific strategy is dependent upon knowledge from other domains. Anderson and Smith (1987) described about teachers changing from didactic or discovery teaching to the use of conceptual change teaching strategies without any explicit instruction in the new strategies that they were observed using. The teachers showed their change to increased knowledge of subject matter and the understandings of their students and this knowledge and understanding are components of pedagogical content knowledge. Similarly, a lack of subject matter knowledge (Smith and Neale, 1989) and a lack of pedagogical knowledge (Marek, Eubanks, and Gallaher, 1990) have been linked to the ineffective use of subject-specific strategies as well. As such, the development of pedagogical content knowledge that is relative with subject-specific strategies requires drawing upon knowledge from each of the three base domains of teacher knowledge: subject matter, pedagogy, and context. There is also evidence that teachers' use of strategies is influenced by their beliefs. Some researchers have documented that some teachers resisted changing their practices to match those of an innovative approach because their beliefs differed from the premises of the new approach (Olson, 1981; Mitchener and Anderson, 1989; Cronin-Jones, 1991).

Knowledge of topic -specific strategies of pedagogical content knowledge refers to teachers' knowledge of specific strategies that are useful for helping students comprehend specific science concept. There are two categories of this type of knowledge; representations and activities. Topic-specific representations refer to teachers' knowledge of ways to represent specific concept or principles in order to facilitate student learning, as well as knowledge of the relative strengths and weaknesses of particular representations. This category includes a teacher's ability to invent representations to aid students in developing understanding of specific science concept or relationships. Some researchers and educators used content representation as topic-specific representation (Geddis *et al*., 1993; Schneider and Krajcik, 2002; Van Driel *et al*., 2002; Zembal-Sual, Krejcik and Blumenfeld, 2002). Science teachers need to know how to use specific representations, how to represent science concept or principles to students, and how to support student thinking. Specific representations could be analogies, illustrations, examples, demonstrations, and simulations. The representation can be illustrations, examples, models, or analogies. Geddis *et al*. (1993) and Wu *et al*. (2001) suggested that representations are viewed as metaphors, models, and theoretical constructs of interpretation of nature and reality. For the example of electricity, there are multiple analogies for representing the concept of an electric circuit: water flowing through pipes in a closed system with a pump, a bicycle chain or a train, or teeming crowds (Hewitt, 1993). The representations help students to link their explanations of the scientific concept (Johnstone, 2000; Dori and Hemeiri, 2003; Wu, 2003) and can serve as a connection between scientific concept and real-world phenomena (Davis, 2003). Importantly, an effective science teacher must judge whether and when a representation will be useful to support and extend the comprehension of students in a particular teaching situation because each analogy has conceptual advantages and disadvantages with respect to the others. In an electric circuit concept, the water flow model reinforces a source-receiver model of electricity and implies that electrons move rapidly in the same direction; a bicycle chain model similarly implies that electrons move in the same direction but does not suggest a source-receiver model; and teeming crowds make it possible to conceive of electron flow in an electric circuit as occurring slowly and randomly, albeit drifting in a common direction. The water flow and teeming crowds' models offer one representation of resistance, whereas a bicycle chain model is limited in representing resistance (Magnusson, Krajcik and Borko, 1999).

Some researchers have reported that limited knowledge of topic-specific representations can negatively impact science instruction. Sanders and her colleagues reported that teachers had difficulty sustaining momentum in a lesson, sometimes confusing themselves and their students when they struggled to respond to student questions requiring more detailed or different representations (Sanders, Borko, and Lockard. 1993). These findings suggest that this type of pedagogical content knowledge may be particularly dependent on subject matter knowledge because the participating teachers were more likely to exhibit these problems when teaching outside of their area of expertise. Despite this claim of the dependence of the development of this aspect of pedagogical content knowledge on subject matter knowledge, having subject matter knowledge does not guarantee that it will become transformed into representations that will help students comprehend scientific concept or that teachers will be adept at deciding when it is pedagogically best to use particular representations. The second category of topic-specific strategies is topic-specific activities. This category refers to knowledge of the activities that can be used to help students comprehend specific concept or relationships; for example, problems, demonstrations, simulations, investigations, or experiments. Pedagogical content knowledge of this type also includes teachers' knowledge of the conceptual power of a particular activity; that is, the extent to which an activity presents, signals, or clarifies important information about a specific concept or relationship. The question of how to decide what activities to use with elementary school students to help them understand the distinction between two scientific conceptions such as diffusion and osmosis should be realizes by science teachers. Smith and Neale (1991) also reported that the elementary school teachers who participated in their four-week summer institute increased their knowledge of activities for teaching about light; however, they also noted that differences occurred among the teachers and that those differences were related to differences in the teachers' subject matter knowledge. For example, only the teacher with strong subject matter knowledge was able to conceive of activities to do with students that were different from those used as part of the summer institute. This dependence upon subject matter knowledge was also described in studies by Hashweh (1987), and Sanders, Borko, and Lockard (1993), both of which investigated teachers in teaching situations within and outside of their areas of expertise. Hashweh reported that when teachers were knowledgeable in a content area, they were able to modify activities included in reference materials and eliminate ones they judged to be tangential to the targeted conceptual understandings. He also reported that teachers with strong content knowledge could devise student activities or demonstrations not mentioned in the references whereas those who were not knowledgeable could not do so.

Moreover, this component of PCK includes science teaching orientation, knowledge of science curriculum and knowledge of assessment of science learning.

The researcher considers that teacher knowledge of instructional strategies should integrate these knowledge domains.

3. Understanding and Practice about Knowledge of Context

This component of pedagogical content knowledge refers to the knowledge teachers must have about community, school, district and student. Especially, knowledge and beliefs about student's context that science teacher should have in order to help students develop specific scientific knowledge. It includes two categories of knowledge: requirements for learning specific science concept, and areas of science that students find difficult. Knowledge of requirements for learning consists of teachers' knowledge about prerequisite knowledge for learning specific scientific knowledge, as well as their understanding of variations in students' approaches to learning as they relate to the development of knowledge within specific topic areas. Teacher knowledge of prerequisite knowledge required for students to learn specific concept includes knowledge of the prior concept, abilities and skills that students might need. Science teachers must know how to help students develop the understandings and skills necessary to collect and interpret experimental data. Teachers' knowledge of variations in approaches to learning includes knowing how students of differing developmental or ability levels or different learning styles may vary in their approaches to learning as they relate to developing specific understandings. Effective teachers are aware of students' differing needs and can respond appropriately

Teachers' knowledge about student conceptions and learning in specific topics is a knowledge base which is needed for teaching a particular subject (Shulman, 1986; Grossman, 1990; Mark, 1990; Geddis *et al*., 1993; Van Driel *et al*., 1998; Vosniadou, 2001; Novak, 2002; Leach and Scott, 2003; Loughran *et al*., 2004; Duit, 2007; Hammer, 2007). Novak (2002) asserted that meaningful learning implies supplanting misconceptions with valid conceptions and those misconceptions operate to distort new learning. As a starting point, science teachers have to know their student conceptions in a particular science topic and student learning difficulties in that topic. This knowledge can guide them in how to implement and provide activities for enhancing their students' learning.

Knowledge of areas of student difficulty refers to teachers' knowledge of the science concept or topics that students find difficult to learn. This rationale for teachers needs to understand that student conceptions and learning is a paradigm shift toward constructivist views of learning. Based on constructivist views of learning, students are seen as people who actively and purposefully construct their own knowledge to make sense of scientific phenomena by using their exiting knowledge and new information (Wheatley, 1991; Bell, 1993; Tobin *et al*., 1994). Referring to constructivist views of learning, science teachers should provide students with activities to shift or modify their own alternative conceptions to accepted scientific conceptions (Bell, 1991; 1993). There are several reasons why students find learning difficult in science, and teachers should be knowledgeable about each type of difficulty. In some science topics, learning is difficult because the concept are very abstract and they lack any connection to the students' common experiences (e.g., the mole, protein synthesis, the sky (sun, moon, and stars), and cellular respiration). For example, elementary students understand that the moon's phases are caused by the movement of clouds while many older students and teachers use the earth's shadow (the eclipse model) to explain the changing phases (Baxter, 1989; Trundle *et al*., 2002; Bell and Trundle, 2009).Teachers need to know which topics fall into this category and what aspects of these topics students find most inaccessible. In these cases, it is important for teachers to be knowledgeable about the kinds of errors that students commonly make, and the types of "real-world experiential knowledge" that they need to comprehend novel problems (Stevens and Collins, 1980). In addition, the difficulty of learning science comes from when student's encounter that learning science involves topic areas in which their prior knowledge is contrary to the targeted scientific concept. Knowledge of this type is typically referred to as misconceptions, and misconceptions are a common feature of science learning (e.g., Driver and Easley, 1978; Confrey, 1990; Wandersee, Mintzes, and Novak, 1994). Scientific concept for which students have misconceptions can be difficult to learn because misconceptions are typically favoured over scientific knowledge because they are sensible and coherent and have utility for the student in everyday life. In contrast, the targeted scientific concept may seem incoherent and useless to the learner. Wandersee, Mintzes, and Novak (1994) caution that attributing students' lack of development of scientific knowledge to interference from misconceptions is misleading in that there is evidence that misconception are not equally resistant to change. As a result they suggest that "it is important to differentiate between the concept that might require high-powered conceptual change strategies and those that are equally likely to yield to well-planned conventional methods," (p.186). Furthermore, others argue that the view of misconceptions as interfering agents that must be removed and replaced ignores the constructivist basis of learning (e.g. Magnusson, Boyle, and Templin, 1994; Magnusson, Templin, and Boyle, 1997). These researchers argue that misconceptions are the product of reasonable, personal sense-making, and that they can continue to evolve and change and result in desired scientific knowledge. Teachers should be knowledgeable with respect to the topics they teach because it will help them interpret students' actions and ideas. Numerous studies have documented students' misconceptions at various levels of schooling and in various scientific domains.

Research about science teachers' pedagogical content knowledge of students' understandings has not been widespread and it indicates that teachers' knowledge about student conceptions and learning difficulty impacts on ways teachers organize activities and content in their classroom teaching (Geddis, 1993; Perterson and Treagust, 1998; Frederick *et al*., 1999; Geddis *et al*., 1999; Bucat, 2004). There are studies that report similar findings and provide some indications of the knowledge those teachers typically have. In one study, the researchers explored teachers' rating of science topics that were difficult for their students but this study did not provide information about why some topics were rated as more difficult than others (Finley, Stewart, and Yarroch, 1982). Therefore, it is not known whether the ratings indicated teachers' knowledge and concerns about students' misconceptions, their difficulties with problem solving, or other issues. Other studies have directly assessed teachers' knowledge of students' understanding. The pattern of findings from this type of study is that although teachers have some knowledge about students' difficulties, they commonly lack important knowledge necessary to help students overcome those difficulties. For example, an investigation of physics teachers' knowledge of students' understandings about force and gravity found that, as a group, the teachers identified nearly all of the common misconceptions that had been identified by the researchers; however, individually, they tended to be aware of only a few common misconceptions and were not aware of all of the misconceptions held by their own students. Moreover, some teachers held common misconceptions themselves (Berg and Brouwer, 1991) A study of elementary school teachers who participated in a project introducing them to conceptual change strategies for teaching about light similarly reported that students' misconceptions about which the teachers were not knowledgeable were ones that they themselves held (Smith and Neale, 1989).

Zambal-Sual *et al*. (1999) argued that in making representations powerful or comprehensible, science teachers should be aware of learners' existing knowledge related to particular concept, as well as the possible problems they are likely to experience with the content. On the other hand, if the teachers do not understand or are not aware of student conceptions and learning difficulties, they will not transform that knowledge when teaching a particular topic (De Jong *et al*., 1999). Such teachers tend to assume those concepts they are teaching are easily understood by students. In a study of the relation between the conceptual difficulties pre-service teachers expect their pupils to have the conceptual difficulties they themselves have or have had. Frederick *et al*. (1999) found that teachers who are not aware of their own conceptual problems will not expect the same problems in their pupils. The lack of awareness of student conceptions and learning difficulties hinders development of teachers' PCK. Frederick *et al*. (1999), Geddis (1993), and Halim and Meerah (2002) argue that this lack of awareness is due to teachers' lack of content knowledge.

Smith and Neale (1989, 1991) indicate that with appropriate in-service experiences, teachers can become more knowledgeable about common alternative conceptions. However, Smith and Neale reported that increased knowledge of students' understandings did not ensure that teachers could respond in appropriate ways when students exhibited misconceptions. They described that even though increased knowledge that supports teachers to pay more attention to their students' thinking than in their previous teaching, and even though some teachers exhibited some successful instances of recognizing and addressing students' misconceptions, in the majority of cases the teachers ignored students' misconceptions or struggled for ways to respond to them. Some undesirable responses by the teachers were to correct the misconception and supply a more detailed explanation rather than probing for the student's reasoning. From this pattern of findings, Smith and Neale concluded that acquiring pedagogical content knowledge does not guarantee the ability to respond effectively during instruction. Their findings may also illustrate the independence of the components of pedagogical content knowledge in that changes in teachers' knowledge of one component may not be accompanied by changes in other components that are also required for effective teaching

In summary, PCK for teaching elementary science level consists of: Subject matter knowledge and beliefs; Pedagogical knowledge and beliefs; and Knowledge and beliefs about context. Effective science teachers are enhanced to integrate three components of PCK to transform knowledge to students. PCK is an important factor to affect on teachers' practice in their classrooms. Each component of PCK model complexly interacts and functions. They are interrelated and integrated with each other. Science teachers need to develop all of these components of PCK because PCK is not only one aspect of knowledge but is integrated knowledge. In the next section, the way of developing science teachers' PCK is presented and discussed. The professional development section relates with PCK components.

Professional Development in Science Education

Professional development [PD] refers to skills required for maintaining a specific career path or to general skills offered through continuing education. It can be seen as training to keep current with changing technology and practices in a profession. The professional is thus engaged in lifelong learning. It helps science teachers understand and change their practices and beliefs as they improve the learning experiences they provide for students within their schools. It can also serve broader purposes: to help teachers develop leadership and change-agent skills which prepares teachers to take a more informed and focused leadership role in fostering the implementation or improvement of the instructional program (Rhoton and Bowers 2001). Professional development refers to involvement by teachers in a variety of activities related to their diverse roles: as curriculum designers and implementers, as administrators and assessors, and as the connection between schools and community (Schibeci and Hickey, 2004).

The recommendations of many reports illustrate a sensible shift from a deficit model of staff development which assumes that teachers are limited in their ability to self-assess what they need to learn to close the gap between school goals and school performance toward a view consistent with the Standards of Professional Development (National Research Council [NRC], 1996a), which recognize teachers of science as "professionals responsible for their own professional development" (p. 55). Over the past 10 years, there are many influential reports about science teacher professional development that have made numerous assertions, including the importance of (1) developing ongoing programs, (2) incorporating current research about how children learn science and how teachers teach science, (3) facilitating collaboration between scientists, teachers, and administrators when designing programs, (4) situating teacher learning within classroom practice, and (5) helping teachers develop a "rich and flexible knowledge of the subjects they teach" (Loucks-Horsley, Hewson, Love, and Stiles, 1998; Loucks-Horsley, Love, Stiles, Mundry, and Hewson, 2003; Borko, 2004; Duschl, Schweingruber, and Shouse, 2007;).

Research conducted by the National Institute for Science Education (Mundry, Spector, Stiles, and Loucks-Horsley, 1999) asserts that teacher learning should be conceptualized as a career-long endeavour and served by a continuous professional development that increase the content and pedagogical needs of both pre- and in-service teachers. Vital features needed for the advancement of lifelong learning of teachers include coherence with policies and other professional experiences (Birman, Desimone, Porter, and Garet, 2000) and coherence of both the principles guiding PD and the establishment of a continuum of offerings (Mundry *et al*., 1999). Effective PD has been described by many researchers (Huberman and Miles, 1984; Gess-Newsome, 2001; Loucks-Horsley, Love, Stiles, Mundry, and Hewson, 2003). There is a wide array of models of effective PD (Drago-Severson, 1994; Guskey, 2000; Sparks and Loucks-Horsley, 1989). Components of effective PD include modeling strategies for teachers (Loucks-Horsley *et al*., 2003); a focus on content of mathematics and science (Birman *et al*., 2000; Garet, Porter, and Desimone, 2001); knowledge and incorporation of inquiry based practices (National Research Council [NRC], 1996); attention to pedagogical content knowledge (Loughran, Mulhall, and Berry, 2003); collaboration between providers of PD and teachers (McCullum, 2000); a focus on changing teacher's beliefs, knowledge, and practice (Mundry and Loucks-Horsley, 1999; Garet, Porter, Desimone, Birman, and Yoon, 2001); sustained PD such that reflection about practice can occur (Gess-Newsome, 2001; Luft, 2001; Loucks-Horsley *et al*., 2003; Adey, 2004;); and the establishment of professional learning communities (Gess-Newsome, 2001; Loucks-Horsley *et al*., 2003), because teacher education is a continuous, lifelong process (NRC, 1996; Mundry *et al*., 1999; Garet *et al*., 2001).

Of the many researchers and theorists who have proposed models of PD, Guskey and Peterson (1996), Loucks-Horsley, Hewson, Love, and Stiles (1998), Guskey (2000), Loucks-Horsley *et al*. (2003) and present the most comprehensive view. According to Loucks-Horsley *et al*. (1998), there are seven features of effective PD: (1) it supports teachers in leadership roles; (2) it links with other parts of the educational system; (3) it helps teachers build content and pedagogical content knowledge and examine their practice; (4) it is research based, engaging teachers as adult learners; (5) it allows teachers to collaborate with colleagues and experts to improve their practice; (6) it is based on student-learning data; and (7) it is driven by a well-defined image of effective classroom teaching and learning.

Guskey (2000) has suggested that there are four main principles of effective PD. These are (1) a focus on learning and learners, particularly the students; (2) an emphasis on both individual and organizational change; (3) the inclusion of small, manageable changes guided by a grand vision; and (4) the continual, embedding of PD in all aspects of a teachers ‘work (e.g., developing and evaluating curricula, instructional activities, and student assessment). The principles of PD promoted through the work of Loucks-Horsley and Guskey are evident in the variety of models that have been researched. According to reviews by Sparks and Loucks-Horsley (1989) and Drago-Severson (1994), the main PD models are training, observation and assessment, study groups, mentoring, action research, and individually guided activities. Especially, Strong, Silver, and Perini (2001) realized that the main focus of PD should be students emphasizing that the only way to see real improvement in students’ scores is by linking the education of teachers to student learning.

The advantages of PD on student learning is proposed by Loucks-Horsley *et al*. (2003) who presents that “effective science professional development should reflect the nature of the disciplines . . . so that teachers in turn can create experiences with their students in the classroom that reflect the nature of doing and learning science and mathematics” (p. 43). Teachers with a better understanding of the characteristics of scientific work are more likely to begin engaging students in challenging mathematical problems and scientific inquiry (Loucks-Horsley *et al*., 2003). They proposed 18 different teacher learning strategies clustered around six categories: aligning and implementing curriculum, collaborative structures, examining teaching and learning, immersion experiences, practicing teaching, and vehicles and mechanisms (Loucks-Horsley *et al*., 2003).

The professional development for primary science teachers is recognized as an important activity which can support improved science education for students (Schibeci and Hickey, 2004). The professional development of practicing primary teachers in science continues to be an important issue worldwide (Grossman, Wilson, and Shulman, 1989; Appleton, 1992; Wallace and Louden, 1992; Aubrey, 1994). Inclusion of PD as a means toward student achievement is included in national standards (e.g., Bybee, Ferrini-Mundy, and Loucks-Horsley, 1997) and supported by instructional manuals to support national initiatives (e.g., Deleuil and Malcolm, 1994). The most important goal of PD involves improving student learning through change in teacher practice. Research on teacher change (Ball and Cohen, 1999) suggests that beliefs only change once teachers observe the beneficial effect on their students. However, Garet *et al*. (2001) suggest that changes in practice occur after new knowledge and skills are acquired. Loucks-Horsley *et al.*'s model of effective PD, although acknowledging the iterative nature of the change process, still implies that a certain commitment to a change in beliefs occurs first, followed by changes in practice, which are then evaluated and which may potentially change teachers' beliefs the research on PD identifies the importance of PD for the advancement of teacher knowledge and skills, pedagogical strategies, and beliefs in inquiry-based instruction. The context of enhancing elementary science teachers to know how to teach a particular subject and construct PCK is a crucial consideration for research in science education. Researchers and educators have investigated what ways encourage teacher to develop their PCK. Therefore, professional development based on constructivist view is developed to encourage teachers learning and changing their existing knowledge. Particularly, in social contexts, teachers construct and reconstruct their own knowledge and beliefs by various methods (Bell, 1993; Tobin *et al*., 1994).

Schuster and Carlsen (2009) embedded case study was bounded by the contextual similarities between seven professional development workshops with the goal of examining the relationship between scientists' views of teachers as professionals and the pedagogical orientations that the scientists used within these professional development contexts. Altogether, the teacher comments and observation data paint a picture of how the instructors implemented specific pedagogical orientations. In particular, the participants in this study appear to have realistic views about the practical roles that research scientists can play. The PD can encourage teacher knowledge and change the purpose of teaching and learning science to be consistent with scientists' views.

In science education, conventional methods of conducting pre-service and in-service education and professional development such as seminars, workshops, and summer institutes, have not always proved to be adequate for attaining the goal of educational reform. In-service workshops conducted all over the world have been usually too short and infrequent to foster a change in teachers' classroom practices. The traditional forms of professional development are widely criticized as being ineffective for increasing the teacher's knowledge. Teachers may adopt the knowledge without concern for the appropriateness in a personal and educational context. Teachers gained the teaching and learning processes from outsiders who were conducting workshops and adapting them into their own personal instruction. Finally, they do not use this knowledge to change their practice because they do not possess the ownership and the empowerment of their teaching (Petretti and Hodson, 1995). There is no continuous development. A paradigm shift in professional development is needed to improve the quality of teachers as a continuous process from their undergraduate years to the end of a professional career (IPST, 2002).

Loucks-Horsley (1995) noted that the principles of effective professional development should be shifted from a top-down approach to a bottom-up one. Professional growth should be derived from teachers' learning and practice. Leadership is another factor which could provide adequate support for teachers to plan and build upon social development in an effort to improve their teaching and learning while working with other teachers in a teacher development program. The professional development should provide opportunities for teachers to maximize students' learning and improve teachers' classroom practices.

In Thai schools, many teachers have qualifications ranging from diplomas to masters degrees in their discipline area (OEC, 2006). The majority of teachers completed a bachelor's degree and a small number of them also hold a lower degree. Moreover, a number of teachers do not have qualifications that match the subject they teach, so many practice out-of-field teaching. Research indicates that most elementary teachers did not graduate with an emphasis on science (Thongkrai, 2000; ONEC, 2001). Many elementary teachers do not appreciate the need for change in their teaching practice in order to reflect current research. It will require considerable input to change their fundamental beliefs and to encourage them to engage in Education Reform activities (Pillay, 2002). Therefore, upgrading the quality and support of teachers is needed (OEC, 2005). Nationwide, the Faculty of Education in the 41

Rajabhat universities (Teacher Training Colleges) managed by the Office of Rajabhat Institute Council take primary responsibility for both prospective teachers and in-service teachers' training. In addition, over 200 university faculties of education also supplement teacher development in Thailand (Pillay, 2002). Science, mathematics, and technology teachers typically receive training conducted by the Institute for the Promotion of the Teaching of Science and Technology [IPST] which provides intensive in-service training for science, mathematics, and technology teachers. The type of professional development in science education in Thailand is mostly an authoritative top-down system of supervision regulated from outside the schools. Although IPST deals with conducting the teacher professional development to push the educational reform of a student-centered approach, the traditional forms of professional development persist. Teachers are usually subjected to the "one-shot workshop", that the IPST developed, or a university developed, using topics from disconnected classes (Lewis, 2002).Teachers learn from teaching-by-telling "experts" instead of constructing their own knowledge (Loucks-Horsley, 1995). This is not truly personal professional development.

Both the Rajabhats and the faculties of education as well as IPST have not made enough of an effort to provide the necessary leadership in understanding and implementing educational reform and teacher development (Pillay, 2002). The teaching approaches delivered to in-service teachers is like a "cookbook recipe" within the workshop or a short course delivering advice on good teaching practices (Kember and McKay, 1996). Since students' learning styles are so varied in heterogeneous class groupings, the recipes for good teaching have not provided solutions to meeting the needs of all students. Furthermore, teachers have difficulty implementing what they have learned in the workshop to the real classroom. Therefore, the promotion of quality of teaching and training activities should aim at shifting from a teacher-centered to a learner-centered approach in accordance with educational reform. Therefore, improved strategy in PD is required to develop and the co-teaching model could be considered a means to correspond with the goals of professional development. The co-teaching model is one of the strategies for professionally developing teachers who engage in co-teaching activities with skilled colleagues who are more aware of their own practices and what their students are thinking, feeling, and learning (Loucks-Horsley, 1995).

Professional development has been identified as a critical component of effective co-teaching models (Freytag, 2003). Co-teaching implementation requires specialized knowledge and skills for both general and special educators. Co-teachers should be confident in their ability to meet the needs of students with disabilities through co-teaching service delivery. General educators must also appreciate the need for accommodations and modifications to the general education curriculum for students with disabilities. Special educators should be familiar with general education curriculum and methods. They must also have the knowledge and skills to suggest instructional strategies to meet unique student needs. Finally, because co-teaching is a partnership, teachers should possess effective interpersonal communication skills. Open, positive communication between general and special educators is critical.

Roth and colleagues (2004) revealed that a co-teacher increases access to social and material resources for the less experienced teaching partner, and thereby increases opportunities for action that otherwise would not occur. Greater teaching opportunities provide newcomers with richer networking experiences. Co-teaching and associated co-generative dialoguing have been proposed in response to the challenges faced by new science teachers in the most difficult schools in the nation (Roth and Tobin, 2002). Many studies has shown that co-teaching is a powerful tool that increase teachers' pedagogical content knowledge that can provides new opportunities for enhancing the learning of high school students and for learning to teach science (Roth and Tobin, 2002; Tobin, Zurbano, Ford, and Carambo, 2003; and Roth, Tobin, Carambo, and Dalland , 2004).

The co-teaching intervention also recognized the concept that a single teacher cannot possess all of the skills and abilities required to effectively address the wide range of learning needs in inclusive classrooms. General-special educator collaboration has been identified as a key vehicle for creating inclusive classrooms and to the mathematics and language arts learning needs of students with disabilities, with general education teachers providing content area expertise and special educators providing strategies that help students learn the content successfully. In the specific case of co-teaching that is reported in this dissertation, two specific interventions were at work: co-teaching involving general and special education teachers and instruction in the grade level content, in an inclusive classroom setting.

The co-teaching model is alternative strategy that is used seldom with PD in Thai context. This model is collaboration between teachers for all of the teaching responsibilities of all students to reach the teaching goals. The co-teaching is discussed in the following section.

The Co-Teaching Model for Science Education

Historical Perspectives of a Co-Teaching

Bauwens *et al*. (1989) were among the first to promote cooperative teaching as a service delivery model to assist students and they defined this model as:

> ...An educational approach is in which general and special educators or related service providers jointly plan for and teach heterogeneous groups of students in integrated settings (Bauwens *et al*., 1989).

The collaborative model has been increasingly embraced as a means to balance both a free and appropriate public education for students with disabilities and the least restrictive environment. While the term cooperative teaching is still recognized, co-teaching is now the term of choice (Hourcade and Bauwens, 2003). Co-teaching has been described in a variety of ways (Cook and Friend, 1995). Cook and Friend (1995), for example, define the co-teaching model as two or more professionals jointly delivering substantive instruction to a diverse or blended group of students in a single physical space. This definition draws attention to the dynamic between teacher, time and knowledge. Many researchers present the co-teaching as a form of situated learning for teacher induction where beginning teachers learn to teach by working side by side with more experienced teachers (Eick, Ware, and Jones, 2004 and Eick and Dias, 2005). Unlike other familiar apprenticeship models in teacher education, co-teaching moves beyond lengthy periods of observation and assistance to a form of team teaching, which is then followed by shared dialogue on practice (Tobin, Zurbano, Ford, and Carambo, 2003). During co-teaching, two or more individuals teach lessons together with one person taking the lead role at any one time. Afterwards, co-teachers reflect together on the co-teaching experience: the enactment of the lesson, intended and unintended outcomes, and collective accountability for student learning. Co-teaching is a means to integrate theory and practice—in practice—what can only be learned in practice and followed by reflective dialogue on practice (Korthagen, 2001). Like other apprenticeship models, learning from co-teaching comes from being in the classroom with another teacher (Roth, 2002).

Friend (2000) asserted: virtually every treatise on inclusive practices, whether conceptual, anecdotal, qualitative, or quantitative, concludes that inclusion's success in large part relies on collaboration among staff members and with parents and others, and that failures can typically be traced to shortcomings in the collaborative dimension of the services to students. As teachers struggle with the daily classroom challenges of trying to close the gap between general and special education, co-teaching and all of its variations has emerged in the field helping teachers to reach their teaching and learning goals. Co-Teaching is as a Service Delivery Model. Bauwens *et al*. (1989) described a merger between general and special educators in which direct educational programming to all students would be provided by having a special educator within a general education setting. To represent this relationship, they coined the term cooperative teaching (Murawski and Swanson, 2001). According to Bauwens *et al*., Cooperative teaching is an educational approach in which general and special educators work in a co-active and coordinated fashion to jointly teach heterogeneous groups of students in educationally integrated setting (i.e., general classrooms). In cooperative teaching, both general and special educators are simultaneously present in the general classroom, maintaining joint responsibilities for specified education instruction that is to occur with that setting. This practice is now better known as co-teaching (Friend and Cook, 1992), though it is also associated with other terms such as collaborative teaching and team teaching. Collaborative teaching is based on the premise that two teachers can learn from each other, combining their strengths to provide both high level content and individualized approaches to raise academic achievement for all students (Rea, McLaughlin, and Walther-Thomas, 2002). Therefore, collaborative or co-teaching are an educational approach designed to provide special education services to students within the restricted context of the general education classroom.

The historical foundations of co-teaching and team teaching are presented in a great deal of literature and many researchers have tried to define these teaching models of their studies. The co-teaching as a special education service delivery model has its roots in a general education practice referred to as team teaching (Friend and Reising, 1993). Team teaching was first introduced in secondary schools in the 1950s. Friend and Reising described the "Trump Model" as typical of the kind of team teaching practiced at that time. The model involved teams of teachers who shared responsibility for large-group presentations followed by smaller group sessions and individualized study. Variations on the Trump Model emerged in the 1960s, and by the 1970s; team teaching was widely practiced in both elementary and secondary schools. Team teaching models now take a variety of forms: professional support systems, shared planning of interdisciplinary units, and shared instruction (Friend and Reising, 1993). Implementation of mainstreaming during the 1970s and 1980s required teamwork between general and special educators and prompted the development of indirect special education service delivery models. Early models featured the special educator in the role of consultant to the general educator. However, according to Friend and Cook (1992), "general education teachers began to make it clear by their reactions that it was inappropriate for special education to assume responsibility for 'fixing' general education" (p. 22). Increasingly, future models were based on a style of interaction that focused on shared expertise and decision-making between special and general educators (Friend and Cook, 1992).While some special and general educators engaged in joint instruction or team teaching in the 1980s, it did not become common practice until the 1990s (Friend and

Reising, 1993) when the inclusive trend started investigation of alternate special education service delivery options (Friend and Cook, 2003). Indirect special education services failed to meet the support needs of general educators. As increasing numbers of restricted contexts, the demand for additional support led to corresponding changes in the roles and responsibilities of general and special educators. These changes resulted in a steady increase over the past decade in the numbers of educators engaged in various co-teaching models (Reinhiller, 1996; Dieker, 2001; Friend and Cook, 2003).

Definitions of a Co-Teaching

Various initiatives have resulted in the emergence of numerous definitions and multiple interpretations of co-teaching (Sindelar, 1995; Reinhiller, 1996; Zigmond *et al*., 2003). Most definitions have five common elements: general and special education teacher involvement, co-planning, co-instruction, heterogeneous groups, and shared physical space (Murawski and Swanson, 2001; Friend and Cook, 2003). For example, Cook and Friend (1995) defined co-teaching as “two or more professionals jointly deliver substantive instruction to a diverse or blended group of students in a single physical space” (p. 1). While co-teaching definitions generally run along similar lines, lack of specificity for implementation of co-teaching elements leaves room for multiple interpretations (Friend and Cook, 2003) and “what is out there in the name of co-teaching” (Zigmond *et al*., 2003) suggests most models are in the early stages of development.

Co-taught classrooms and teacher roles are discussed in different ways. The rationale for co-teaching is based on the premise that the general educator and the special educator combine individual expertise to benefit all students. Ideally, skilled special and general educators bring not only an extra pair of hands, but also highly specialized instructional techniques to co-teaching relationships (Friend and Cook, 2003). The special education teacher provides additional support in the classroom and supplements the content area knowledge of the general education teacher with knowledge and expertise related to teaching students with disabilities or restricted contexts (Rea *et al*., 2002). The special education teacher has expertise in learning styles, learning strategies, behaviour modification, diagnostic or prescriptive teaching, and accommodations, and the general education teacher has expertise in content area, scope and sequence of curriculum, presentation of curriculum, large group management strategies, and an objective view of academic and social development (Basso and McCoy, 1997). The delivery of coordinated and substantive instruction by both teachers is recognized as the hallmark of true co-teaching (Gately and Gately, 2001; Friend and Cook, 2003).

Hourcade and Bauwens (2003) noted that joint and simultaneous direct provision of instruction is the most distinctive feature of the cooperative teaching model. Students require increased student-teacher interaction, frequent feedback, close monitoring of skill acquisition, and additional planning for instruction. Co-teaching offers opportunities for these enhanced learning options. High involvement teaching strategies afford all students in co-taught classroom with increased opportunities for active participation and teacher interaction (Friend and Cook, 2003). The main purpose of co-teaching is that the presence of two teachers with individual expertise will lead to both qualitative and quantitative differences in instructional delivery as compared to what is possible in a classroom taught by a single general education teacher (Friend and Reising, 1993).

In a co-taught classroom, teachers share the planning, presentation, evaluation, and classroom management in an effort to enhance the learning environment for all students. In this way, the teachers can provide more integrated services for all students, regardless of learning needs. Teachers involved in collaborative partnerships often report increased feelings of worth, renewal, partnership, and creativity (Friend and Cook, 1992). Teachers working in co-teaching classrooms move through a developmental process politely, building interactions to truly collaborative relationships. Based on these definitions and type of co-teaching models, the major goals of co-teaching model are to bring practical improvement, change and development of social practices, and get more experience. Beginning teachers may benefit most in learning to teach by co-teaching with an experienced teacher (Roth, 2002). Inexperienced teachers model in practice specific traits or attributes of an experienced teacher, such as gaining proficiency in asking productive questions (Roth and Boyd, 1999; Roth, Masciotra, and Boyd, 1999). Tobin *et al.* (2003) found in one case study that a pair of student teachers modeled their experienced teacher's mannerisms that were suited to successfully teach and interact with students in their urban classrooms.

Types of a Co-Teaching Model

According to Sindelar (1995), "There seem to be about as many different ways for teachers to collaborate as there are pairs of teachers collaborating, and individual teachers may take on many different roles in their various collaborations with colleagues" (p.238). Variations in co-teaching arrangements are based on co-teaching definitions as well as internal and external factors (Weiss and Lloyd, 2002). Bauwens *et al.* (1989) described three cooperative teaching options: complementary instruction of the educator who is responsible for teaching subject matter whiles another educator assists students with academic survival skills; team teaching that joins planning and delivery of instruction by educators. Cook and Friend (1995) further delineated these roles identifying five commonly implemented co-teaching structures: one teach, one assist, station teaching, parallel teaching, alternative teaching, and team teaching. One teaches and one assist are the crucial aspect of the co-teaching model. Of the five structures identified by Cook and Friend (1995), the one teach, one assist structure is the most frequently implemented co-teaching format (DeBoer and Fister, 1998; Welch, 2000; Weiss and Lloyd, 2002). In this structure both teachers are present in the classroom. One teacher, usually the general educator, is responsible for instruction and the other circulates and provides assistance and support to individual students or small groups (Cook and Friend). The teacher in the assist role travels around the room monitoring and assisting students as needed. Researchers have cautioned, in this role, many special education teachers act as support personnel performing at the level of a paraprofessional (Vaughn, Schumm, and Arguelles, 1997; Weiss and Lloyd, 2002; Friend and Cook, 2003). For this structure to be most effective, the support offered by the assisting teacher must be highly specialized (Heward, 2003) and clearly defined (Dieker, 2002).

In 1993, Friend, Reising, and Cook identified five options teachers typically use when implementing a co-teaching model. These types are hierarchical across three variables. First, as moving down the continuum of models, more and more planning time together is needed. Second, as progressing in the models, teachers need an equal level of content knowledge to make the model work effectively. This equality of content knowledge can be the greatest barrier to team teaching at the secondary level. Third, as moving down the continuum, teachers must share the same philosophy of inclusion and have a level of trust and respect. Typically, this level of trust and respect has to be built over time, which also is another reason it is sometimes difficult to team teach at the secondary level or in larger schools, if there is not consistency over time in building team support. Key aspects of each type of co-teaching are provided below.

Lead and Support is one who is one teacher who leads and another who offers assistance and support to individuals or small groups. In this role, planning must occur by both teachers, but typically one teacher plans for the lesson content, while the other does specific planning for students' individual learning or behavioral needs.

Station teaching relates with students who are divided into heterogeneous groups and work at classroom stations with each teacher. Then, in the middle of the period or the next day, the students switch to the other station. In this model, both teachers individually develop the content of their stations.The station teaching structure involves division of the content to be delivered. Each teacher takes responsibility for a portion of that content and delivers instruction to a group of students at one station or center. The number of stations may vary since students may also work independently, but over time, all students generally participate in all stations (Cook and Friend, 1995; Welch, 2000). This arrangement requires additional planning and preparation, but allows for active learning, increased student response rates, and exposure to more information (Freytag, 2003). Important considerations include the provision of explicit instructions and effective monitoring of activities for students working independently (Burello, Burello, and Friend, 1996).

Parallel teaching focuses on teachers jointly planning instruction, but each may deliver it to half the class or small groups. This type of model typically requires joint planning time to ensure that as teachers work in their separate groups so they are delivering content in the same way. The parallel teaching structure involves joint planning of instruction by both teachers. The class is divided into two heterogeneous halves and each teacher delivers essentially the same instruction to one half of the class (Friend and Reising, 1993; Welch, 2000). In this structure, a reduced student-teacher ratio allows for increased student participation and attention; however, efforts must be made to regulate the noise level and make physical arrangements to accommodate two simultaneous lessons in one classroom (Freytag, 2003).

Alternative teaching is one teacher works with a small group of students to pre-teach, re-teach, supplement, or enrich instruction, while the other teacher instructs the large group. In this type of co-teaching, more planning time is needed to ensure that the logistics of pre-teaching or re-teaching can be completed; also, the teachers must have similar content knowledge. The alternative teaching format is also referred to as skill groups (DeBoer and Fister, 1998), enrichment groups (Welch, 2000), or review/remediation groups (Welch). Essentially, this format involves separating a smaller group of students from the larger class for a specific skill need (e.g., pre-teach, re-teach, supplement, or enrich) (Dieker, 2002). It allows for a smaller student/teacher ratio and more intensive, individualized instruction. Burello *et al*. (1996) stressed the importance of changing student groupings to avoid the negative effects of continually separating the same students from the class for remedial assistance.

Team teaching relates to both teachers who share the planning and instruction of students in a coordinated fashion. This type of co-teaching needs joint planning time, equal knowledge of the content, a shared philosophy, and commitment to all students in the class. Planning and instructional delivery is shared in the team teaching format. Teachers jointly plan and deliver instruction interchangeably (Weiss and Lloyd, 2002). This format resemble the one teach, one assist format except that teachers switch roles throughout the lesson. Dieker (2002) stressed that utilization of this structure is dependent upon teachers having sufficient planning time, equal levels of comfort with the curriculum, and similar teaching philosophies.

Dieker (2001) observed nine co-teaching teams. Of those, four were functioning in the lead-support model; four used the team teaching model; and one team used a variety of models alternating between, parallel teaching, alternative teaching, station teaching, and team teaching. Dieker also identified a unique structure used by two teams referred to as cross-family support. In this model, a special educator was assigned to a team of content area teachers. One day a week, the content area teacher brought his or her classes to the special educator’s classroom for activity-based learning related to an interdisciplinary theme. It is not necessary to use only one type of co-teaching model; teachers can start with lead and support firstly and they can move to be team teaching in the next step. Much researches focused on lead and support type of co-teaching between cooperating teachers and pre-service teachers during student teaching (Eick, Ware, and Williams, 2003: Eick, Ware, and Jones, 2004 and Eick and Dias, 2005). Context and teachers ability are important criteria for selecting which types of co-teaching model should be integrated with a professional development strategy.

Moreover, Gately and Gately (2001) also proposed components of a co-teaching model that emphasize curriculum goals, teaching philosophy beliefs, assessment, instruction, instruction planning, familiarity with the curriculum, physical environment, and interpersonal communication. They were interested in the stages of the co-teaching process and argued that co-teaching is a developmental process. Like any developmental processes, it has stages through which co-teachers proceed. They have identified three developmental stages in the co-teaching process: the beginning stage (guarded, careful communication), the compromise stage (give and take communication, with a sense of having to give up to get), and the collaborative stage (open communication and interaction, and mutual admiration). At each developmental stage in the co-teaching process, teachers demonstrate varying degrees of interaction and collaboration.

Friend and Cook (2003) stressed the importance of a positive collaborative working relationship as the foundation for successful co-teaching. Effective co-teaching requires a high level of commitment and a high degree of coordination (Friend and Riesing, 1993). They noted partners must have an understanding of each other's instructional beliefs, recognize the importance of parity in the relationship, reach agreement on classroom routines, discipline, feedback, and classroom noise level, and respect each other's specific triggers or pet peeves. Environments that support the development of strong co-teaching relationships require administrative and logistical support. Walther-Thomas and Bryant (1996) outlined comprehensive planning for co-teaching and identified multiple issues to be addressed by program planners at the district and building level. Freytag (2003) identified and investigated nine crucial factors associated with successful co-teaching models recurrent in the literature including administrative support, balanced classroom rosters, common planning time, training and staff development, voluntary participation, teacher voice, communication, parity, and teacher efficacy in the instruction of students who receive special education. Freytag's investigation revealed close interrelationships between factors. Teachers' self-perceptions of self-efficacy in the instruction of students who have restrictive contexts were found to be the single most important factor contributing to teachers' overall perceptions of co-teaching. This finding highlighted the importance of not only specific conditions supporting effective models, but also classroom practice. Effective co-teaching characteristics and practices are prevalent in the literature.

Dieker (2001) investigated characteristics of effective middle school co-teaching teams and identified multiple conditions and practices. These included positive perceptions of co-teaching, positive learning climates, scheduled planning time, instruction centered on active learning, high expectations for academic performance and behaviour, and multiple, methods used to evaluate student progress. The number of factors associated with effective models detail the complexities involved in co-teaching implementation. Further, variations in co-teaching models suggest educators differ in the values they assign to each of these characteristics. Even within a single school, there may be wide variation in teachers' interpretations of the model (Dieker, 2001).

The co-teaching model is a primary strategy used to focus on integrating with developmental research in education. Researchers have studied how teachers develop collaborative relationships, restructure and adapt curriculum and instruction, and share responsibilities for planning, instruction, and evaluation for the benefit of all students (Dieker, 2001; Fennick, 2001; Weiss and Lloyd, 2003). Weiss and Brigham (2000) identified more than seven hundred studies describing some type of co-teaching. Welch *et al*. (1999) conducted a review of the team teaching literature since 1980 in an effort to determine "the score and game plan on teaming in schools" (p. 36). Their findings highlight the need for more student centered evaluations and in particular investigations of learning outcomes to provide empirical support for co-teaching as a service delivery model for students with disabilities. Teacher perceptions of co-teaching efficacy have provided insight into benefits of the model (Rice and Zigmond, 2000). According to Welch *et al*. (1999), a comprehensive evaluation of the literature revealed that what is known about co-teaching is that teacher attitudes toward shared responsibility in the inclusion of students with disabilities are improving and attitudes and satisfaction with various forms of teaming are favourable. Identified teacher benefits include increased professional satisfaction and opportunities for professional growth, personal support, and increased opportunities for collaboration (Walther-Thomas, 1997). Minke and Bear (1996) found teachers perceived instructional adaptations desirable, but practical only in the context of a skilled, compatible co-teaching team.

Austin (2001) surveyed 139 collaborative teachers. Most agreed co-teaching was a worthwhile endeavour contributing to teaching effectiveness in restrictive settings. The co-teaching, cited in s, reduced the student-teacher ratio, increased the expertise and viewpoints of teachers, improved remedial strategies for all students, increased acceptance of learning differences by peers. According to Walther-Thomas, co-teaching benefits reported for students included improved academic performance, more time and attention from teachers, increased emphasis on cognitive strategies and study skills, increased emphasis on social skills, and improved classroom communities.

Zigmond and Magiera (2001) maintained that the intentions of co-teaching are to provide a wider range of instructional alternatives, to enhance the participation of students in co-taught classrooms, and to improve the performance outcomes of students. Those intentions are more likely to be fulfilled in co-taught classrooms when teachers implement a variety of sharing formats. For teacher education, Eick, Ware, and Williams (2003) found that methods students involved in co-teaching with experienced teachers gained confidence in their ability to teach through enhanced teacher presence and practical knowledge. This practical knowledge included growing classroom management skills and the ability to implement inquiry-based activities that promote conceptual understanding (NRC, 1996). The study of the special education program intervention of co-teaching specific content areas was important to the district leaders because the intervention represents a strategy to increase educational opportunities and outcomes for education students in the district. Achieving this goal has always been a priority of district leaders.

Although co-teaching model seems to be effective for helping teachers to meet students' needs but many studies propose the problems of working between two teachers. These problems come from the variations in implementing co-teaching. Weiss and Lloyd (2003) found major differences in co-teaching models when they observed six special educators in co-teaching arrangements. They identified internal and external pressures or causal conditions influencing co-teaching roles. Conditions included scheduling pressures, content understanding, acceptance by general educators, and the skills of the students who receive special education. These conditions influenced the adoption of one of four roles: providing support to students, teaching the same content in separate classroom, teaching separate content in the same classroom, and teaching as a team. Challenges and obstacles to co-teaching include: co-teaching places multiple demands on teachers, and requires thorough preparation in collaborative strategies and techniques (Villa *et al*., 1996; Walther-Thomas, 1997). Potential problems cited by co-teachers include lack of professional development opportunities in the area of co-teaching and limited classroom support in the early stages of implementation. Teachers report difficulties with the compatibility and flexibility of team members, finding planning time, curricular development, ethical and professional issues, classroom management, assessment issues, and efficient communication (Friend and Riesing, 1993; Winn and Messenheimer-Young, 1995; Reinhiller, 1996; Vaughn *et al*., 1997; Duchardt *et al*., 1999; Austin, 2001). Negative attitudes toward inclusion also have been identified as barriers to successful implementation of co-teaching models (Minke and Bear, 1996; Rice and Zigmond, 2000).

Loveland, McLeskey, So, Swanson, and Waldron (2001) found teachers with experience in positive, successful inclusive school programs showed significantly more positive perspectives regarding inclusion than teachers who had not been in inclusive programs. Non-inclusion teachers expressed concerns about the preparation of their school for inclusion, their possible roles and functions in an inclusive program and the influence on students without disabilities. Similarly, Freytag (2003) found teachers with low levels of self-perceived efficacy did not view co-teaching favourably. Administrative support and guidance for teachers in the initial stages of co-teaching implementation should be designed to address negative attitudes (Walther-Thomas and Bryant, 1996). The limited role of the special educator is most frequently cited as a concern with the model (Sindelar, 1995; Austin, 2001; Dieker, 2001; Weiss and Lloyd, 2002; Friend and Cook, 2003). Co-teaching takes many forms ranging from true partnership to differentiations and subservience (Sindelar, 1995). Factors impacting the role of the special educators include the amount of time available for shared planning, the content area knowledge of the special educator, the level of trust between co-teaching partners, and the level of academic need of the students with disabilities in the co-taught classroom (Dieker and Murawski, 2003; Gately and Gately, 2001). Weiss and Lloyd (2002) identified lack of common planning time as a factor impacting parity in co-teaching partnerships. Shared instruction is less feasible without adequate shared planning time. However, Austin found that while special and general educators indicated the value of shared planning, instructional duties, and classroom management, they did not necessarily share those responsibilities in practice. Dieker and Murawski (2003) found, given the opportunity for shared planning, general and special educators tended to team with faculty in their own departments. Weis *et al*. noted that teacher preparation issues, content and scheduling, and state-mandated curricula impacted general and special educator roles in co-taught classrooms. Teachers face multiple challenges in the implementation of co-teaching. Walther- Thomas (1997) attempted to provide a summary of those challenges, identifying a lack of sufficient, deliberately scheduled planning time, scheduling of students into co-taught classes, excessive caseloads for special educators, varying levels of administrative support, and absence of staff development as primary impediments. Gately and Gately (2001) identified three developmental stages in co-teaching relationships: the beginning stage, the compromise stage, and the collaborative stage. Ideally, co-teachers will move through these stages as the teaching relationship develops.

Therefore, as outlined in the literature, the co-teaching model is vehicle driver for developing teacher ability in special students and context. There are many factors that occur along with efficacy of this strategy. As such, the progress research should consider these factors for developing higher qualitative and more successful professional development. Dieker and Murawski (2003) offered a practical approach to the challenges of the model. They wrote, "Expect progression through stages one of the primary components of successful co-teaching is per of the process and the willingness to be flexible as the process develops" (Dieker and Murawski (2003:p. 6).

As increasing numbers of students who study in restrictive environments continue to move into general education settings, there are corresponding increases in the numbers of general and special educators engaged in varied co-teaching models (Hourcade and Bauwens, 2003; Reinhiller, 1996). The collaborative approach has gained widespread acceptance (Friend and Cook, 2003). However, co-teaching lacks a solid empirical database supporting its efficacy in terms of student outcomes and in-service teacher education (Fuchs and Fuchs, 1996; Weiss and Brigham, 2000).

The interesting tendency is that co-teaching is more interested to encourage surrounding highly qualified teachers. Importantly, the term, highly qualified takes on new meaning in light of full realization of the restrictive environment of teachers who together know what and how to teach students and who together have a command of the subject matter being taught, for enhancing their pedagogical content knowledge.

Dieker (2001) investigated characteristics and practices associated with effective co-teaching teams at the middle school and high school level, and identified conditions and practices. The findings highlight the need for more student centered evaluations and in particular investigations of learning outcomes to provide empirical support for co-teaching as a service delivery model for students who receive special education. This study had an underlying assumption that the primary purpose of co-teaching is to increase the success of students who receive special education within the general education environment. This study provided an opportunity for data collection and analysis of student performance in the mathematics and language arts curriculum utilizing a co-teaching model.

From the previous example, elementary teacher education is still not focused to develop with the co-teaching model. In Thai education, increasing teacher knowledge through professional development is very interesting for educators and developers, and many international studies emphasize the use of the co-teaching model with their teacher education programs; the co-teaching model is used seldom as frequently during teacher education in Thailand. Therefore, this study is interested in the co-teaching model, especially the characteristics of team teaching for developing professional development in Thailand. From a review of past research, collaborative, team, and co-teaching are presented as the same model. The co-teaching model is used with developing professional development in this study. It is a model that emphasizes collaboration and communication among all members of a team to meet the needs of all students. These teams come together for a common purpose, typically to meet the needs of a wide range of learners more effectively. The factors to successful co-teaching are three critical issues including co- planning, disposition, and teaching and evaluating. All members of the co-teaching team share a common goal of developing the two teachers' practices of teaching science concept through an inquiry-based approach. Therefore, this study emphasizes the components of the co-teaching model that area; curriculum goals, teaching philosophy beliefs, assessment, instruction, instruction planning, familiarity with the curriculum,physical environment, and interpersonal communication (Gately and Gately, 2001). In addition, the co-teachers will be encouraged to develop from a beginning stage to a collaborating stage during their practice.

In summary, the literature suggests that teachers who hold knowledge of only subject matter or pedagogy are not well enough equipped for teaching particular content in a particular context, and it cannot be guaranteed that science teachers will develop their own PCK. Effective teachers should integrate various domains of knowledge. The collaborative approach is focused as a way to encourage teachers communicating and sharing their knowledge and experience. Teachers will develop their pedagogical content knowledge and they will have an opportunity to learn. In conclusion, the co-teaching model (Hourcade and Bauwens, 2003; Gately and Gately, 2001) is an interesting alternative strategy for professional development in Thailand.

Summary

The review of literature of teachers' learning to teach science and science teacher education in the Thai context has outlined that all dimensions of pedagogical content knowledge and professional development can lead to the principle for developing interventions and a design research methodology. PCK in this study is seen as teachers' knowledge that enables them to transform particular science content knowledge into forms that are understandable for heterogeneous groups of students. In summary, PCK for teaching elementary science level consists of: Subject matter knowledge and beliefs; Pedagogical knowledge and beliefs; and Knowledge and beliefs about context. Subject matter knowledge and beliefs and pedagogical knowledge and beliefs are blended into PCK that considers on integrating with knowledge and beliefs about context. Effective science teachers are enhanced to integrate appropriated strategies into specific content knowledge. Therefore, when they transform their content knowledge to students, the teachers will present their understanding or conception of that science topic. Pedagogical knowledge and beliefs that is used specific to science concept will present about knowledge and beliefs about purposes and goals of teaching science, knowledge and beliefs about science curriculum (specific goals, objectives and material), knowledge and beliefs about assessment in science (dimension of student learning and method of assessing student learning), knowledge and beliefs about instructional strategies for teaching science, and knowledge and beliefs about learner and learning.

The last component of PCK model is knowledge and beliefs about context that includes knowledge and beliefs about context of community, school, district, and student. In aspect of student context is focused on students' alternative conceptions, student learning in science, and requirement for learning. Each component complexly interacts and functions as parts of PCK. They are interrelated and integrated with each other. Science teachers need to develop all of these components of PCK because PCK is not only one aspect of knowledge but is integrated knowledge.

Encouraging teachers' PCK through professional development is a crucial aspect to increase the quality of science teachers. Professional development is needed for science teachers to maintain and develop specific career paths or for general skills offered through continuing education. It can be seen as training to keep current with changing technology and practices in a profession. The professional is thus engaged in lifelong learning. It helps science teachers understand and change their practices and beliefs as they improve the learning experiences they provide for students within their schools. Science teachers will have up-date knowledge to teach students with meaningful strategies and they can enhance their students to be scientific literature. One strategy of PD that relates with the collaborative approach is the co-teaching model. Teachers will gain chances to communicate and exchange their knowledge and idea, as well as being able to discuss and find ways for solving classroom problems.

The next chapter, Chapter III, provides the methodology to find out data required for answering the research questions of this study. Qualitative research using an interpretive multiple within-case study will be discussed as well as interpretivism as the research theoretical framework, and grounded theory as the research methodology will be presented.

CHAPTER III

RESEARCH METHODOLOGY

Introduction

The main purpose of the study is to develop and evaluate the effectiveness of a co-teaching model to enhance elementary science teachers' PCK. The purpose of this study is discussing the results of a pilot study (Chatmaneerungcharoen and Yutakom, 2009) which aimed to investigate the understanding of Thai elementary science teachers about the knowledge that they should integrate into their classroom practices. As a result of the pilot study, a need of various domains of teachers' knowledge was identified. These essential results were used to design a CTM to enhance elementary science teachers' PCK. Therefore, the pilot study inspired to find effective strategies to help teachers' developing their PCK.

The chapter III presents educational research paradigm, theoretical framework, research methodology, research context, research participants, research design, and data collection and data analysis. This study is qualitative research using an interpretive multiple within-case study. Interpretivism will be used as the research theoretical framework and grounded theory will be used as the research methodology.

Educational Research Paradigm

For many years it has been common to place the process of engaging in research alongside experiencing and reasoning as the principal ways in which people attempt to understand their environments (Cohen and Manion, 1985). As Emery (1986) proposed, the characteristics of research are as follows:

> ...Research is an ancient and ubiquitous activity. Curiosity about others and the worlds in which they live has always been displayed through conversation,

> asking questions, working together to see what happens after different kinds of actions are performed, talking or gossiping about others to tease about intentions and other reasons for behavior, clarifying and understanding circumstances; all are fundamental research function.

Candy (1989) has argued that the research process is a natural human function. Harry Wolcott, the famous educational anthropologist, suggested a way of thinking to help one engage in these related processes of clarifying the issue and narrowing the focus. His position is that as inquiry proceeds, the idea that prompted it should become both better formed and better informed (Wolcott, 1992). He suggested three categories which form a modest typology of the ideas that guide inquiry: reform-driven ideas, concept-driven ideas, and big theory driven ideas. This research is undertaking particular types of research from the point of view of Wolcott's third category of ideas that guide inquiry. Wolcott's third category is states that ideas that guide inquiry encompass those ideas that relate to an overall grand or big theory. The argument running throughout is that educational research can be underpinned by one of four major big theories such as, positivism, interpretivism, critical theory, and postmodernism (Donoghue, 2007).

Similarly, in Kuhn's work, concept of paradigm are defined both as "the entire constellation of beliefs, values, techniques, shared by members of a given scientific community" (Kuhn, 1970: 75) and as "an exemplar or exemplary way of working that functions as a model for what and how to do research, [and] what problems to focus on and work on" (Usher, 1996: 15). A paradigm shift involves a new way of looking at the world and hence new ways of working, or new ways of doing 'normal' science. Epistemological and ontological assumptions are proposed along with research methodology according to specific paradigms. Guba and Lincoln (1994) presented a chart that illustrates a range of frameworks which are helpful in locating and clarifying the paradigm within which researchers might wish to locate their research. They proposed an important aspect that all educational research is either implicitly or explicitly to be conducted within a framework of theoretical assumptions. Each paradigm is based upon sharply different assumptions about epistemology, which involves the study of how knowledge is generated and accepted as valid, and about what the purposes of research are. The traditional period is associated with the positivist, foundational paradigm. The modernist or golden age and blurred genres moments are connected to the appearance of positivist arguments. At the same time, a variety of new interpretive, qualitative prospective were taken up to be interesting for educational research. The researchers who work in educational field are needed to understand why people think or act in specific contexts. Qualitative inquiry is the name for a reformist movement that began in the early 1970s in the academy. The movement encompassed multiple epistemological, methodological, political, and ethical criticisms of social scientific research in fields and disciplines that favored experimental, quasi-experimental, co-relational, and survey research strategies

The researchers who are based on the interpretivist paradigm emphasize social interaction as the basic for knowledge. They use their skills as social beings to try to understand how others understand their world. Knowledge, in this view, is constructed by mutual negotiation and it is specific to the situation being investigated. From changing the paradigm, qualitative research has rapidly been established to be an acceptable approach within a broad range of disciplines. Educational and social work research has also adopted qualitative methods given their reliance on interaction as a key component of professional practice.

The qualitative research is a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible (Denzin and Lincoln, 2003). This research involves a variety of empirical material such as case study; personal experience; introspection; life story; interview; artifacts; cultural text and productions; and observational, historical, interactional, and visual texts. These texts describe routines and problematic moments and meanings in individuals' lives. The qualitative researchers are allowed to access these embedded processes by focusing on the context of people, where such decisions are made and enacted. The researchers are seen as bricoleur, as a maker of quilts, or, as in filmmaking, a person assembles images into montages (Denzin and Lincoln, 2003). However, the use of multiple methods, or triangulation, reflects an attempt to secure an in-depth understanding of the phenomenon in question. Triangulation is not a tool or strategy of validation, but an alternative to validation (Flick, 1998). The choice as to which interpretive practices to employ are not necessarily set in advance. The choice of research practices depends upon the questions that are asked, and the questions depend on their context (Nelson *et al*., 1992).

In conclusion, all qualitative researchers are philosophers in that "universal sense in which all human beings... are guided by highly abstract principles" (Bateson, 1972: 320). These principles combine beliefs about ontology (what kind of being is the human being? what is the nature of reality?), epistemology (what is the relationship between the inquirer and the known?), and methodology (Lincoln and Guba, 1985; Guba, 1990). These beliefs shape how the qualitative researchers see the world and acts in it. The researcher is bound within a net of epistemological and ontological premises which become partially self-validating (Bateson, 1972). The net that contains the researcher's epistemological, ontological, and methodological premises may be termed as a paradigm, or an interpretive framework, a basic set of beliefs that guides action (Guba, 1990). In the next section, the interpretivist paradigm and the basic foundation principles of interpretivism are discussed. A brief historical account of interpretivism as it unfolds in the form of symbolic interactionism is then outlined.

Interpretivism as a Theoretical Framework

From an interpretivist point of view, what distinguishes human (social) action from the movement of physical objects is that the former is inherently meaningful. Thus, to understand a particular social action, the inquirer must grasp the meaning that constitutes that action. To say that human action is meaningful is to claim either that it has a certain intentional content that indicates the kind of action it is or that what an action means can be grasped only in terms of the system of meanings to which it belongs (Outhwaite, 1975; Fay, 1996). To find meaning in a human action or to understand what a particular action means requires that one interpret in a particular way what the actors are doing (Denzin and Lincoln, 2003). Dilthey (1958) argued that to understand the meaning of human action requires grasping the subjective consciousness or intent of the actor from the inside. This interpretivist stance is explained in Collingwood's (1946, 1961) account of what constitutes historical knowledge, and it lies at the heart of what is known as objectivist or conservative hermeneutics. Major lenses for studying this context have been provided by a number of research approaches. The necessity of understanding people's contextual realities before introducing changes in the hope of improving the quality of education in any context is well summarized by Fullan (1982).

For the interpretivist, the individual and society are inseparable units. From this, it follows that a complete understanding of one is not possible without a complete understanding of the other. Under the umbrella of interpretive research design, a naturalistic research setting is an important characteristic. Naturalistic means that the researchers do not attempt to manipulate or control the research setting (Lincoln and Guba, 1985). Because in this view, the research setting is subject to change, it is impossible to control and manipulate participants and the setting (Patton, 2002). Interpretive researchers believe that realities are wholes that cannot be understood in isolation from their contexts. In other words, the individual participants cannot be separated from social environments such as their program, classroom, school, community, and so on. Rather, individual participants have social interactions with others and their social environments. Patton (1990) point out that in such a holistic view, a description and understanding of a person's social environment or an organization's political context is essential for overall understanding of what is observed. When the researchers collect data, they gather not only one perspective and one attribute of the phenomena, but also multiple aspects of the setting under study. The data of multiple aspects provides a comprehensive and complete picture of a particular context. Therefore, researchers use as many kinds of data collection methods as possible, and look for consistency of finding across different methods.

Interpretive research primarily employs an inductive research strategy. It builds abstractions, concept, hypothesis, or theories. Bryman (2001) and Fenstermacher (1986) suggest that interpretive qualitative research is concerned with the generation of data rather than testing of theories. Typically, qualitative research findings are in the form of themes, categories, typologies, concept, and tentative hypotheses, even theories, which have been inductively derived from the data. Lincoln and Guba (1985) argue that interpretive researchers prefer inductive data analysis because the inductive process is more likely to identify the multiple realities to be found in those data. However, there has been much debate on the issues of whether or not the positivist research paradigm is entirely suitable for social science or educational research. Post-positivists or interpretive argue that reality can only be fully understood through subjective interpretation and intervention. In contrast to the positivist view, the interpretive argues that individuals' interpretations or understanding of the world around them have to come from the inside, not the outside (Cohen and Manion, 1994). This understanding of the phenomena of interest is called subjective or emic. Behrens and Smith (1996) and Merriam (1998) contend that interpretive research is aimed at understanding the meaning people have constructed, that is, how they make sense of their world and the experience they have in the world. Interpretive researchers believe that studying only one variable of individuals' attributes is not enough to understand the meaning people have constructed in a complex and manifested world. Therefore, to strive to understand individuals' attributes is not enough to understand individuals as a whole (Lincoln and Guba, 1985; Bryman, 2001; Freebody, 2003). These holistic views of social phenomena result in research questions of interpretive views different from the traditional positivist views. The interpretive researcher asks, for example, about the conditions of meaning that students and teachers create together and about the conditions of meaning that students and teachers create together, as some students appear to learn but others do not, rather than ask which behaviors by teachers are positively corrected with student gains on tests of achievement (Erickson, 1986).

The study reported in this thesis is aimed at identifying how a PCK-based science co-teaching model impacts on the development of in-service elementary science teachers' PCK, and how they develop their PCK during a co-teaching model. The researcher views educational environments such as classrooms, CTM, and schools as a complex world. The elementary science teachers in these educational environments are persons who construct their own knowledge and interpret the meaning of the social world to develop their PCK. The researcher thus believes that an interpretive methodology can provide appropriate directions to conduct the research in order to reach the answers to the research questions. Interpretivism is therefore employed as a framework to find out the meaning of how elementary in-service teachers learn and construct their own PCK in specific contexts. This research framework can help the researcher to capture the complexities and contextual factors in natural settings that impact the development of elementary science teachers' PCK. In the following section, the characteristics of grounded theory are discussed as a research methodology of this study. Many interpretive researchers proposed that a variety of research methods such as observations, interviews, and document review can provide the complex and holistic view of what teachers know, how teachers act, and why they do so. Therefore, case study, observations, interviews, and document review are discussed in the next topics.

Grounded Theory as the Research Methodology

Research methodology is the philosophical basis which provides researchers directions of how to select particular techniques and methods for gathering, collecting, or interpreting data. The research methodology is derived from a paradigm which presents a distillation of what the researcher thinks about the world (Lincoln and Guba, 1985). A methodological paradigm has an important role in the conduct of research because it is the philosophical foundation underlying types of research.

Bogdan and Billen (2003) described "methodology" as a more generic term that refers to general logic and theoretical perspective for a research project, but "methods" is a term that refers to the specific techniques that the researchers use, such as surveys, interviews, and observation. They proposed that good research should be designed using methods that are consistent with the logic of methodology (Bogdan and Billen, 2003).

If researchers have different paradigms, that is, if they believe or think about the world in different ways, they may use different research methodologies to answer their research questions (Merriam, 1998; Patton, 2002). For example, a researcher who believes that reality is stable and can be observed and described from an objective view without inferring the phenomena being studied (Bryman, 2001; Merriam, 1998) is regarded as positivist. The positivist researcher believes that there is a single tangible truth "out there" that can be separated into pieces of variables (Lincoln and Guba, 1985), and that variable and process can be studied independently. When positivist researchers do research, they thus apply the methods of natural science to answer their research questions. They typically try to manipulate reality with variation of a single independent variable to examine regularities in, and to form relationships between, some of the constituent elements of the social world (Lincoln and Guba, 1985; Erickson, 1986; Cohen and Manion, 1994).

This study was conducted by using the grounded theory methodology. Grounded theory is described as a research methodology where the researchers use results to inform how to gather additional data for creating theory (Locke, 2001; Charmaz, 2003; Henwood and Pidgeon, 2003; Dey, 2004). Instead of creating a formal theory, the researcher tried to generate conceptual analyses of particular experiences of phenomena by using empirical evidence for generating and reefing ideas (Charmaz, 2003; Seale *et al*, 2004). Grounded theory derives its theoretical underpinning from pragmatism (Dewey, 1925; Mead, 1934) and Symbolic Interactionism (Thomus and Znaniecki, 1918; Park and Burgess, 1921; Blumer, 1969; Hughes, 1971). Grounded theory is built from two important principles. The first principle pertains to change. Since phenomena are continually changing in response to evolving conditions, an important component of the method is to build change, through process, into the method. The second principle pertains to a clear stand on the issue of determinism. Strict determinism is rejected, as is nondeterminism. People do not response to only conditions but they can be able to make choices according to their perceptions. Both pragmatism and symbolic interactionism share this stance. Thus, grounded theory seeks not only to uncover relevant conditions, but also to determine how actors respond to changing to conditions and to the consequences of their actions. The data from grounded theory can come from various sources. To explain the effectiveness of a co-teaching model, the researcher used a variety of research methods including interview, observation, documents, and questionnaires. This variety of methods represented an 'openness and flexibility of approach' (Charmaz, 2003).

Znaniecki (1934) lists several steps in the analytic induction process: (1) develop a hypothetical statement drawn from an individual instance, (2) compare that hypothesis with alternative possibilities taken from other instances. Therefore, the social system provides categories and classifications. The next step is (3) comparing aspects of a social system with similar aspects in alternative social systems. The emphasis in this process is upon the whole, even though elements are analyzed as are relationships between those elements. It is not necessary that the specific case being studied be "average" or representative of the phenomena in general. Consistent with Cobin and Strauss (1990), O'Donoghue and Punch (2003) present that in grounded theory the whole process of data collection and analysis is a tightly-woven iterative process. In grounded theory, the analysis begins as soon as the first data collection. In addition, grounded theory involves constant comparison, which leads to the gradual development and refinement of theory grounded in the data. This constant comparative method involves systematic cracking, coding, and analysis of the data, beginning of the early stage of data collection on the basic of the evolving hypotheses. This process of increasingly focused data collection is called theoretical sampling (O'Donoghue and Punch, 2003).

Table 3.1 The Stages of Research Practice in Grounded Theory
Source: Glaser and Strauss (1967) and Dey (2004).

Stage	Glaser and Strauss (1967)	Dey (2004)	Purposes	Processes
1	Comparing incidents applicable to each category	Open Coding	Assigning the key word or categories from data	-Accounting name of data -Comparing data in term of coding -Writing memo
2	Integrating categories and their properties	Axial Coding	Developing and organizing the conceptual categories	-Comparing conceptual elements -Clarifying the relationships between categories
3	Delimiting the theory	Selective Coding	Settling on the framework's theoretical components and clarify the story to tell about the phenomena.	-Integrating and delimiting theory and its constituent categories -Clarifying analytic stories by comparing the developed categories or frame work with related ideas
4	Writing the theory		Producing a research article for publication	-Using memos and coded data to build theory

From Table 3.1, the first stage is called comparing incidents applicable to each category (Glaser and Strauss, 1967) or open coding (Dey, 2004). Researchers aim to assign some key words or categories to data. These key words represent a common meaning that is composed into conceptual category. A theorist works with conceptualization of data. Activities in this stage concern naming or coding and writing memos comparing incidents and naming like phenomena build the common term. A theorist accumulates the basic units for theory. A set of categories and some related properties emerged from the first stage.

The second stage is named integrating categories and their properties (Glaser and Strauss, 1967) or axial coding (Dey, 2004). This stage aimed to explore the interrelationship of each category and connect them into a conceptual framework. Concept that pertains to the some phenomena will be grouped to form categories. Not all concept become categories. Categories are higher in level and more abstract than the concept that represents data. Concepts are generated through the analytic process of making comparisons to highlight similarities and differences that are used to produce lower level concept. Categories are the cornerstones of a developing theory. They provide the means by which a theory can be integrated. In other words, over time, categories can become related to one another to form a theory. In grounded theory, representativeness of concept is crucial. The aim is ultimately to build a theoretical explanation by specifying phenomena in terms of conditions that give rise to them, how they are expressed through action or interaction, the consequences that result from them, and variation of these qualifiers. The aim is not to generalize findings to a broader population per se (Corbin and Strauss, 1990).

The third stage is named delimiting the theory (Glaser and Strauss, 1967) or selective coding (Dey, 2004). Corbin and Strauss (1990) identified selective coding that is the process by which all categories are unified around a core category, and categories that need further explication are filled-in with descriptive detail. This type of coding is likely to occur in the later phases of a study. This stage aimed to further refine the categories to develop theory. The researcher integrated and delimited theory from prior information. This stage is the stage of theoretical saturation' which means subsequent data incidents that were examined provide no new information (Locke, 2001) or further data collection and analysis does not significantly change the model being developed (Taber, 2000). The last stage was only described by Glaser and Strauss (1967). In this stage called “writing of the theory”, the researcher aimed to produce a research article by using memos and coded data in writing theory to describe the research study.

From the stages of using grounded theory methodology in conducting research, coding is an important process to generate categories of data. These categories were gradually elaborated and refined during the process of research (Taber, 2000). Coding is the fundamental analytic process used by the researcher. In grounded theory research, there are three types of coding: open, axial, and selective (Corbin and Strauss, 1990). In some grounded theory studies, researchers have had difficulty making a commitment to a core category. They always have to struggle with the problem of integration playing one analytic scheme against the other to see which captures the essence of what the research is all about (Glaser, 1978; Strauss, 1987; Corbin and Strauss, 1990).

The generalizability of a grounded theory is partly achieved through a process of abstraction that takes place over the entire CTM of the research. The more abstract the concept, especially the core category, the wider the theories applicability. At the same time, a grounded theory specifies the conditions under which a phenomenon has been discovered in this particular data. A range of the situation to which it applies or has reference is thereby specified. In utilizing theory, practitioners or others may encounter somewhat different or not-quite the same situations, but still wish to guide their actions by it. They must discover the extent to which the theory does apply and where it has to be qualified for the new situations.

This PCK Study is based on the interpretive research framework and conducted using grounded theory as its research methodology. Interpretive research primarily employs an inductive research strategy. It builds abstractions, concept, hypotheses, or theories. Therefore, multiple data sources are important for producing theory. Typically, qualitative research finding are in the form of themes, categories, typologies, concept, tentative hypotheses, and even theories, which have been inductively derived from the data. The inductive approach is evident in several types of qualitative data analyses, especially grounded theory (Strauss and Corbin, 1990). It is very similar to the general pattern of qualitative data analysis described by others (e.g., Miles and Huberman, 1994; Pope *et al.*, 2000). Inductive approaches are intended to aid an understanding of meaning in complex data through the development of summary themes or categories from the raw data (data reduction). These approaches are evident in many qualitative data analyses. Some have described their approach explicitly as inductive (e.g., Backett and Davison, 1995; Stolee, Zaza, Pedlar, and Myers, 1999) while others use the approach without giving it an explicit label (e.g., Jain and Ogden, 1999; Marshall, 1999). Lincoln and Guba (1985) argue that interpretive researchers prefer inductive data analysis because the inductive process is more likely to identify the multiple realities to be in those data.

Multiple Data Generation Methods

There is confusion in using the words methodology and method in conducting research. The term of method used in educational research is different from the term methodology. Bogdan and Billen (2003) describe 'methodology' as a more generic term that refers to the general logic and theoretical perspective for a research project, but 'method' is a term that refers to the specific techniques that researcher use such as survey, interviews, or observation. There are many technical aspects of the research depending on what kind of data that researchers want to collect. The method chosen depends in part on the methodology used. Particularly, they suggested that good research should use methods that are consistent with the logic of methodology (Bogdan and Billen, 2003). Similarly with Cohen and Manion (1994) who proposed that method refers to specific techniques and procedures used to gather data which are used as a basis for inference and interpretation, while methodology is aimed at describing an understanding of the process of inquiry including data collection and analysis. For interpretive research, the researcher is a research instrument that needs to get close to the participants or context for data collection. They need to think about where the researchers need to be searching, with whom, and in what relationship (Erickson, 1986). In interpretive research, multiple methods are considered to give multiple perspectives of phenomena and these methods are employed to gather data. Researchers also need to carefully consider which methods of gathering data are appropriate for a particular purpose. In the next section, multiple methods of assessing teachers' PCK are described followed by the characteristics and strengths and weaknesses of each method of gathering data including observation, interview and document review. In addition, case study, which is used as the research design in this study, is presented and discussed.

Case Study

A case study is defined and described from the perspective of interpretive methodology. It is regarded as an interpretive research design (Merriam, 1998). A case study was used during and after the co-teaching model. This design aims at gaining an in-depth understanding of a particular unit or bounded system such as an individual, program, event, group, intervention, or community (Bell, 1993; Cohen and Manion, 1994; Meriam, 1998). Patton (1990) argues that case studies are selected for study because they are of particular interest for a particular study's objectives. Case study is particularly useful when the researchers need to understand a unique situation. This particularistic feature of case studies makes it an especially good design for practical problems for questions, situations or puzzling occurrences arising from everyday practice (Merriam, 1998; Cohen, *et al*., 2000). Studying a particular unit or system does not mean that case study provides simple principles of study. Stake (1994) proposes that in studying the case, many researchers will gather data on the nature of the case; its historical background; the physical setting; other contexts including economic, political, legal, and aesthetic; other cases through which this case recognized; and those informants through whom the case can be known. Theoretical insights and complexity from case study results reflect on the educational practice. Case study data can inform educators or any readers to clearly understand new meaning of the phenomena, extend their experiences, or confirm what it is known

(Merriam, 1998). The four important properties of case study defined by Merriam (1998) are particularistic, descriptive, heuristic, and inductive.

a) Particularistic: research focuses on a specific situation or phenomena

b) Descriptive: the research provides a holistic interpretation of situation

c) Heuristic: an understanding of a situation in the research was generated by participants and the researcher

d) Inductive: the researcher uses the inductive approach to generate understanding from data.

The other feature of a case study is focusing on attempting to document the story of a naturalistic phenomenon (Denscombe, 1998; Merriam, 1998; Freebody. 2003). Case study brings about insights and holistic views of particular phenomena. Case studies contain rich, thick description in order to describe the insight views. Thick description refers to complete, literal description of the incident or entity being investigated. Johnson and Christensen (2000) and Merriam (1998) argue that the thick description is necessary to illustrate to the readers the phenomena of study. The rich descriptive data can come from any methods of data collection, from testing or questionnaires to interviewing (Cohen and Manion, 1994; Freebody, 2003). These descriptive data are then used to develop conceptual categories or to support theoretical assumption prior to the data gathering. A thick description of a case study provides readers with information of a process happening in natural phenomena. A case study researcher is interested in process and context more than outcomes and specific variables. However, cause and effect in the phenomena also describe happening in a particular context. Cohen *et al*. (2000) argue that studying cause and effect in the context is strength of case study. The researchers can observe cause and effect in complicated and real contexts.

Case study research has advantages that give and present a rich and holistic account of particular real life situations; however, there are some criticisms of the methods and comments about its limitations. Critics of the case study research design draw attention to its time-consuming nature and generalizability limitations.

In addition, Merriam (1998) proposes that the research report of case study design may be long and detailed making it difficult to read. Therefore, to solve this problem, the researchers should provide a summary for readers. Another problem of case study research is generalizability. Some critics point out that generalizability is not usually possible in case study research (Bell, 1993; Denscombe, 1998; Lincoln and Guba, 1985; Merriam, 1998). Because case study is generally studying a single case, it cannot generalize from that case to other cases which usually have different characteristics (Stake, 1994). Dealing with this concern, multiple case study and cross-case analysis are used. Merriam (1998) argues that multiple case studies can give greater variation across the cases, and enhance the external validity or generalizability of the research finding.

In this research study, multiple case studies are used as research design. This study fulfils the characteristics of the case study design above. Particularly, how particular elementary science in-service teachers develop their PCK in a particular setting, using the co-teaching model. It is naturalistic in that it takes place in naturalistic contexts and science elementary in-service teachers are not manipulated. The cases are bounded by time (one year data collection), place (the co-teaching model), and subject (science). This study attempts to describe contexts and settings. Multiple sources are used to provide holistic and in-depth collection of data. Multiple methods of assessing teachers' PCK and details of each data collection method are discussed below.

Multiple Assessment Methods of Teachers' PCK

Because using multiple complementary methods is most effective for assessing PCK (Baxter and Lederman, 1999), many researchers use various methods for investigating teachers' PCK. PCK does not consist of only one aspect of knowledge but it is integrated knowledge. PCK is a complex construct and it not easily assessed (Baxter and Leaderman, 1999); researchers and educators have to develop different techniques and methods for assessment corresponding to their own research frameworks.

Baxter and Leaderman (1999) propose three categories of methods: convergent and inferential techniques, such as likert-types self scales, multiple choice items and short answer formats; concept mapping, card sorts and pictorial representations; and multi-methods with triangulation. The convergent and interferential techniques that are presented are suitable to investigate teacher knowledge of student conceptions and learning difficulties. If researchers want to investigate teachers' content knowledge, concept mapping, card sorting, and pictorial representation should be used to identify teachers' knowledge. The assessment methods that are mentioned are generally used to assess teachers' cognition rather than their practices in real classrooms.

In addition, there are many researchers who focus to understand not only teachers' cognition but they also include teachers' practice in the classroom. Kagan (1990) argues that teachers' cognition cannot be assessed directly because sometimes teachers may have good PCK and they may show this clearly in their practice, but they may not be able to articulate their own knowledge. Many techniques are used to investigate teachers' knowledge through their practices such as Louhran *et al*. (2001) and Penso (2002) who used vignette and a teaching diary in which teachers were required to describe their teaching and the learning which occurred in their classrooms. This vignette and teaching diary did provide the description of what was happening with teaching and learning, but not the reasons behind their actions (Loughran *et al*., 2001). Cannolly and Cladinin (2000) have highlighted the importance of teachers' stores and in so doing, have illustrated that sharing experience through narrative is one way of accessing teachers' knowledge and practice. Teachers seem naturally drawn to discussing teaching by drawing stories of their experience because they include the rich detail that accompanies the context crucial to understanding not only what happened, but also how and why. In many ways, teachers' stories actually extract their own meaning from a given description of a teaching and learning situation.

Conle (2003) also believes 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 the causes aspects of the tacit to become more explicit, therefore resulting in personal and professional changes in the reader, and to their visions of what can be. And that is at the heart of why teachers' stories are often powerful, not only for the story-teller but perhaps more importantly, for the reader or listener. Teachers' PCK has to be considered both internal and external constructs and researchers who investigate this teacher knowledge should focus on what teachers know, how they think and act, and why they do (Baxter and Lederman, 1999).

Trustworthiness is important. Different data sources are used to enhance validity and cross-checking of the findings. The multiple methods are classroom observation, interviews, and teachers' documents (Baxter and Lederman, 1999). For example, De Jong (2000); Van der Vark and Broekman (1999) integrate to use lesson planning and interview to evaluate the validity of data. De Jong *et al*. (1999) suggest that teachers' preparation of the lesson plan can inform aspects of a teachers' PCK because the lesson plans require integrated knowledge. Teachers will be presented their knowledge of the curriculum, knowledge of pupils, knowledge of instructional strategies, and knowledge of assessment. Moreover, there are many researchers that use other methods such as classroom observation, teachers' documents, and interview into multiple methods evaluation. Classroom observation can be used to identify teachers' practice and student learning and their interactions. Observation data can be supported by interview data and documentary data. Clermont *et al*. (1993) and Zembal-Sual (2000) use a videotape to enhance teacher reflection on their own or other teaching. Many researchers use interview to collect in depth participants' data and to support with other data. Other sources of data are written documents such as teachers' portfolios, journals, reflections, and lesson plans. Therefore, if researchers and educators investigate teachers' PCK, they should consider getting data from different sources to increase validity. From literature review, there are many methods to investigate teachers' PCK. These methods include likert-type self report scales, multiple-choice items, short answer formats, concept mapping, Card sorts, teachers' written documents, classroom observations, and interview. Multiple-method is important to help researchers obtain a correct result. This result is interpreted from internal and external constructs. In doing so, multi-methods evaluation could be a research tool used to assess teachers' PCK in aspects of what teachers know, how teachers act, and why they do so (Baxter and lederman, 1990).

In this research, classroom observation, interview, questionnaire, case study, card sort and documents were used as research methods to provide opportunities for participants and the researcher to generate an understanding for a particular situation. Research participants present their PCK through writing lesson plans, teaching journals, meeting, card sorting, and answering or discussing topics in the interview process. An understanding of their PCK was transcribed and explained by the researcher who has used the inductive approach to generate theory.

Context of the Study

This part provides background information including the research site where the study was conducted, characterization of the elementary science teachers who volunteered to participate in this research study and a description of the processes for initiating and establishing the PCK- based co-teaching model.

Research Site

This study was conducted in elementary school governed by the Office of the basic education commission. The school located in Nontaburi province in suburban area of Bangkok Metropolitan. The school has two semesters per year; the first semester ran from May to September and the second semester ran from November to March. The school breaks in each academic year in October.

This study was conducted at Wattanawan School. The school enrolls students from kindergarten to grade 6. However, the study focused only on science elementary teachers who taught at higher primary level which involved students in the 4^{th} – 6^{th} grades. The details information regarding the school is described below.

Wattanawan School was a public elementary school located in Nontaburi province. This school is situated in the suburb with a lower and middle class of families. The school was established in 1950. To date, this school had 4 buildings, one outdoor sport field, a science laboratory, an ICT room, a language room, a botanical garden, a green house, and a library. The school also has received tremendous support from the office of basic education commission for scientific materials and equipments. In 2009, the number of students attending in this school was approximately 1,200. There were 430 students in the higher primary school level: 4 classes of each grade 4, 5 and 6. The class sizes ranged between 35-40 students. In this year, Wattanawan hired 80 government teachers under the support of the office of basic education commission. According to the school record of students' achievement in Science, the average grade was 2.5-3 in the 2007 academic year. The vision of this school is community participation, emphasizing on self-discipline, environmental conservation, technology and English as a knowledge tool. The schools objectives are focusing on learning and morality, contributing to Thai community, understanding and applying advanced technology, and being good member of society.

In Wattanawan School, students came from lower or middle class families. Their parents were workers, merchants, or agriculturists. Most students did live in the vicinity of the school communities. They stay with their families who have old family in that area. With respect to teaching and learning science, the higher primary level students learned science 3 periods per a week (one hour/period). Therefore, they studied science 120 hours a year. In the 2009 academic year, science subject in the school was taught based on the National Science Curriculum Standards [NSCS] (DCID, 2002).

Participants

Since research in educational field gradually change to focus more on qualitative way, the purpose of the research also move to interest in how to understand small group of people or research sample in deeply explanation. When the researches focused on a small group, they can obtain greater information and develop an in–depth understanding to their situations. In addition, the generalization is not the major goal of educational research. Purposeful sampling is brought to find the research sample as selection strategy. This sampling method is based on the criteria that the researcher would like to learn and find the answer for research questions. From the questionnaire, the last section of the questionnaire contained a brief description about this research and teachers were asked to participate in this larger study of PCK based co-teaching model (Chatmaneerungcharone and Yutakom, 2009). There were 33 questionnaires returned (73.33%) to the researcher. Once the teacher indicated yes, they were screened based upon their responses to what would be their motivation for being part of the large study group. Twenty teachers (60.61%) indicated their willingness to participate in the study. In the end three criteria were used for choosing the participants and they were as follows:

a) Teachers who were teaching Science subject in the upper elementary levels in the same school. They were science teachers in grade 4, 5 and 6.

b) The teachers were teaching Science in both semesters and could participate in both phase of the study.

c) They showed a willingness to contribute to the profession by being open to classroom observations by the researcher, participate in follow-up interviews and be able to attend meeting of the PCK based co-teaching model.

Subsequently, the researcher visited teachers in school and had conversations with the school administrators regarding the study plan. Therefore, the participants in this study were three elementary science teachers who were teaching at the upper elementary level (Level Standard 2, grades 4-6) in public schools under Office of the Basic Education Commission. They were purposive sampling selected from thirty-three teachers who completed questionnaires during the second semester of the 2009 academic year. Three elementary in-service teachers completed a questionnaire and were interviewed to collect data and in how they worked their school situations. They came from diverse backgrounds and academically training in their universities. To protect their privacy they were given pseudonyms, Ms. Malai, Ms. Napaporn, and Mr. Sirod. In the first semester of the 2009 academic year, these elementary science teachers were provided with the co-teaching model which was developed to become the PCK based co-teaching model of this research. The following section and Table 3.2 describes the teachers' education backgrounds and their situations.

Teachers' Background

Case Study I: Ms. Malai

Ms. Malai, who was 50 years of age at the time of the study, has a Bachelor's degree of Social education. She had been teaching Social subject for 24 years. Since 2006, she has been teaching in Science subject for 3 years. There were 35 students per classroom. She taught in Science subject for 12 hours to 15 hours per week. In addition to teaching in classroom, she had the reasonability to do school accounting and consulter for 4th grade students. For school curriculum, she only selects books and makes lesson plans that are taught following the school curriculum. She had responsibility of teaching science in grade 4 and she volunteered to do even though she did not have strong background in Science. It is for reason that she attended several workshops and took CTM related to the area of Science during school holidays.

The workshops and CTM covered theoretical knowledge related to Science for grade 4 as well as provided her with opportunities for practical field experiences. During 5 years, the following is a list of some of the Promotion of Teaching Science and Technology, IPST; the Department of Education, Faculty of Education, Kasetsart University; and Educational Districts. The many workshops she attended covered topics such as: making teaching and learning material, making teaching and learning assessment, designing lesson plan, using teaching strategies and knowledge directly related to the field of Science. Even though she attended many workshops, she still cannot be confident to teach science.

Case II: Ms. Napaporn

Ms. Napaporn was 53 years old; she graduated with a degree of physical education. She has 11 years teaching experience in science subject. In previous years she taught science in the lower primary levels. For the past ten year, she has been teaching in 5th grade in Science subjects. There were 40 students per classroom. She has to teach in science subject for 12 hours to 24 hours per week. She taught this subject area even though it is not her area of expertise. In addition to teaching in classroom, the teacher has many responsibilities to do such as student's consulter for 5th grade students, laboratory teacher, activity teacher, scout teacher and the head of the Science department. In 5 years, teacher A has been attended with many workshops provided by educational institutions and her school. These workshops focus on curriculum, lesson plan, instructional media, teaching method, and learning and teaching assessment. She also participated to create school curriculum including selecting manual books.

Case III: Mr. Sirod

Mr. Sirod was 38 years in-service elementary teacher. He graduated from Bachelor of Arts major in Agricultural education. In 10 years previous he taught Agricultural Subject in the lower primary levels. For 1 year and 11 months, he has been teaching in grade 6 for Science subject. There were 40 students per classroom. He had to teach in science subject for 12 hours per week. He taught this subject area even though it is not his area of expertise. More than teaching in classroom, the teacher had many responsibilities to do such as consulter section for 6th grade students, laboratory section, audiovisual section and students' activities section in this school. In 5 years, he has been attended with many workshops provided by educational institutions and his school. These workshops and CTM covered theoretical knowledge related to curriculum, lesson plan, instructional media, teaching method, science content, and learning and teaching assessment. For school curriculum, he only selected books that are taught following the school curriculum.

Table 3.2 Teacher's Background

	Teacher's Background		
Name	Malai	Napaporn	Sirod
Gender/Age	Female/50	Female/53	Male/38
School of teaching	Wat-ta-na-wan school**		
Level of teaching	Grade 4^{th}	Grade 5^{th}	Grade 6^{th}
Science Teaching Period (Week)	12 Hours (4 Classes per Semester)		
Teaching experience	28 years	32 years	15 years
Science teaching experience	3 years	11 years	1 years 11 months
Education background	Bachelor's degree in Education (Social Study) Master Degree in Educational Administration	Bachelor's degree in Education (Physical Education)	Bachelor's degree in Education (Agricultural Education)

* Pseudonym of the teachers

** The school was public school which was funded by the government. Students did not pay for any fees while they studied in the schools.

School Backgrounds

The study was conducted in only one school that fell under the Jurisdiction of Nontaburi Provincial Primary Education Office. Wattanawan School has been open since December 5th, 1950. The school situated in a middle class suburban community. There were 1200 students from kindergarten to grade 6. These students were all divided into 26 classes with classroom sizes ranging from 30-45 students. The total teaching staff was 80, 5 of which have Master Degrees and the rest Bachelor Degrees. The science department consisted of 12 teachers, 3 of which had Masters Degrees and the rest Bachelor Degrees.

Research Design

The design of the research reported here is divided into two main phases according to the research objectives. The first phase describes data collection and analysis and investigates the impact of the PCK based co-teaching model on teachers' PCK development. The second phase describes data collection and analysis, and strategies enhancing trustworthiness and it attempt to understand how science elementary teachers develop their PCK during the co-teaching model. This research composes of 4 phases which include:

CTM I: Exploration (July-September 2009),
CTM II: Preparation (October-November 2009),
CTM III: Co-Planning (December 2009), and
CTM IV: Co-Teaching and –Evaluating (January-February 2010).

The phases are outlined in Figure 3.1

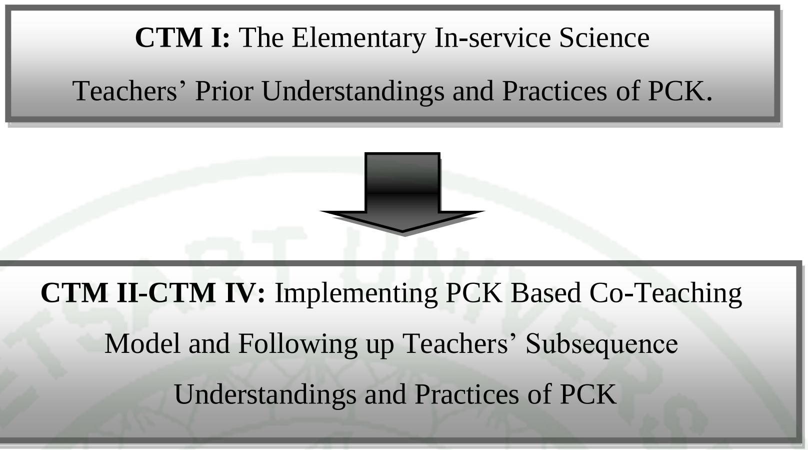

Figure 3.1 Research Phases

CTM I: Exploration

The first phase of the research design is aimed at investigating how elementary science teachers understand PCK and how to construct a co-teaching model. This phase involved with designing the CTM model took place during the 2009 academic years. The first research question is: what is the prior understanding of elementary science teachers' pedagogical content knowledge? And the second question is: what are the characteristics of a co-teaching model designed to facilitate Thai elementary science teachers' development of pedagogical content knowledge? To answer these questions, the researcher reviewed documents that described the expectations of teacher professional knowledge from standards in Thailand. The researcher analyzed the level of expectations of the Standards for teaching profession (4^{th}) of teachers' council of Thailand (1999) and National plan for reforming in teacher education and development of educational personnel (ONEC, 1995). Moreover, the model was developed by considering information from the preliminary data of a pilot study, a literature review of teaching and learning science based on constructivism and the inquiry approach, science education in Thailand, professional development strategies, and the co-teaching model. The process of developing co-teaching and the details of this model are described in chapter 4. Interpretive multiple cross case studies were used as the research design to study the impact of the co-teaching model on the development of teachers' PCK. The multiple case study design provided the opportunity to observe the growth of each science elementary teacher's PCK from the beginning to the end of research. Grounded theory was employed to generate theory from research data.

CTM II- CTM IV

The second phase of this thesis aimed to examine how the in-service teachers developed their PCK during the CTM. It is a follow-up phase to explore the effects of a CTM on the development of in-service teachers' PCK and to investigate the factors constraining or supporting PCK development. The purpose of this phase is to find out answers to the two main research questions.

A multiple case study design was used to study the development of in-service teachers' PCK and constraints or supports of their PCK development while engaging with the CTM. To answer these research questions, the data collection methods used in phase II were classroom observation, semi-structured interview, and document review.

PCK Based a Co-Teaching Model [CTM]

Goals of the CTM

The CTM was designed for accomplishing two ultimate goals: 1) to promote elementary science teachers' understanding of PCK and 2) to enrich the elementary teachers' practice in their actual classrooms focusing on inquiry based teaching and learning. Throughout the CTM, the three elementary science teachers learn to improve their PCK and the use of Inquiry based teaching and learning via the repetition of sharing-reflecting cycle and the meetings of the CTM.

CTM Team

There were five persons who were involved in the CTM. These people were called the CTM team. The CTM team comprised of three science teachers who taught at upper elementary level, one researcher, and one science educator. The team members had a shared goal. Their common goal was to promote the elementary science teachers' understanding of PCK and practice of inquiry based teaching and learning in their real classrooms. The meetings were held at both the central meeting sites; the Faculty of Education and the office at school. Hence, the "CTM Team" term used in this study referred to not only when all members of the team met at the central meetings, but also when co-teachers worked with the researcher in the small meetings.

Role of CTM Members

Role of the Researcher

The researcher's roles on the CTM were that of the co-teacher and teacher's assists. As a co-teacher, the researcher was to work with other co-teachers by parity, mutual respect, specific mutual goals, shared accountability for outcomes, and sharing knowledge and resources. For assistance, the researcher was to facilitate and assist each teacher in their developing of PCK and practices through the work in the stages of co-teaching model and the meetings of the CTM team. For small meetings, the researcher assisted the co-teachers regarding the development of PCK and the production of inquiry-based lesson plans, the implementation of the lessons, and the points of PCK when they confronted difficulties or confusions in understanding and practice. The researcher facilitated the teachers by video -recording their inquiry-based teachings and sharing the videos to the co- teachers to observe and reflect on regarding their instruction. For the central meetings, the researcher organized the activities that helped to promote the teachers' knowledge of PCK in their classrooms. The researcher also provided the teachers with useful references regarding PCK. The researcher interviewed each teacher several times throughout the research and collected the teachers' inquiry-based lesson plans and written reflections. The researcher also was one of co-teachers who shared ideas and experiences with others in the CTM team. In addition, the researcher monitored and videotaped the teachers' implementations of inquiry-based lessons and discussed these events with the CTM team at the central meetings. During the monitoring, the researcher was a participant observer.

Role of the Co-Teachers

As CTM Team members, the teachers experienced all of the activities set up in the CTM. They worked collaboratively with the CTM team through the repetition of sharing-reflection cycles. For the small meetings, co- teachers designed inquiry-based lessons, their lessons, implement their lessons, observed their own teaching practice, and wrote a reflection on their instruction. For the central meetings, the three teachers brought their lesson plans, teaching experiences, difficulties/problems of the teaching and their co-teaching that occurred in the classroom to share with the CTM team. The team members critiqued the components of inquiry-based lessons and the essential features of PCK, provided suggestions to their colleagues for improving lessons, supported their peers' success, and identified what they had learned in terms of PCK. The teachers then translated their knowledge of PCK into a new inquiry based lesson for the next sharing-reflection cycle. Through this process the researcher anticipated that the teachers would gradually develop and refine their understandings and practices of PCK.

Role of Science Educator

As CTM team member, the science educator became a consultant for the teachers and the researcher. The science educator provided suggestions and feedbacks to the co-teachers about their lesson plans and teaching practices. She also encouraged the teachers to reflect on their own instructions by raising questions and issues for the CTM team discussions. However, it was important to note that the science educator assisted the co-teachers individually in aspect that the co-teachers still were confused and she attended only when the CTM team met at the central meetings. For small meetings, the science educator did not consult with the teachers directly. Nevertheless, she supported the teachers by editing their lesson plans and giving feedback. The researcher then brought her suggestions to the teachers and talked with them regarding the issues that the teachers did not understand.

CTM Team Meeting

For sharing and reflecting of all of the CTM team, there were five meetings that occurred at central meeting site (also referred to as central meetings). The rest of the meetings were held at the schools (referred to as small meetings). The major goal of the central meetings included: 1) to provide the science teachers with the opportunity to share their understandings and practices of PCK focusing on inquiry-based lesson plans, teaching experience, and difficulties in understanding and implementing the lessons; 2) to assist and support each other in improving inquiry-based lessons; and 3) to learn PCK through share and reflection on their own instruction, communication with each other, and participation in activities provided in the meetings. For small meetings, the primary aims of the meetings were to facilitate co-teachers to work through the sharing-reflection cycle and to assist them regarding the area that they found difficulties in understanding and practice of PCK including in designing their inquiry based lesson plans. All meetings that occurred in this study were video- or audio-recorded. The five central meetings were set up in a medium size lab classroom in the Faculty of Education, Kasetsart University. The small meetings commonly occurred in the teachers' science classrooms or offices. More detail of the meetings is provided in the section below. The schedule of overall meetings and topics discussed in small meetings are shown in Appendix C.

CTM Procedure

This study set out to enhance the teachers' elementary science classrooms in the context of a professional development program, entitled the CTM. At the beginning of the CTM, the CTM team had to establish a common goal for participating in this professional development program. There was also a need to gather information on what the teachers already knew and practiced in relation to PCK. Thus, the CTM began with the exploration phrase in which the common goal was generated and the teachers' understanding and practice of PCK were examined. The CTM I: exploration phase was followed by three phases of sharing-reflection with the co-teachers: CTM II, CTM III and CTM IV. Thus, the CTM consisted of four phases which included: CTM I, CTM II, CTM III and CTM IV, respectively. The details of each phase are knowledge and the use of PCK in described as follows:

CTM I: Exploration

The exploration phase took place from July, 2009. This phase started at the beginning of the first semester launching from July. In July 2009, after the school administers and participants agreed to be involved in the study, the researcher sent consent letters to the Dean of the Department of Education, Kasetsart University for approval. After being approved, the consent letters were sent to the school administrator and then to the participants. At the beginning of July the researcher went to school and met each teacher at the school in order to set up the common goal of the CTM, to consult with teachers regarding the CTM procedure, and to inform the teacher about their role and obligation as a member of the CTM and a research participant. The researcher also visited the teachers at their schools regularly. The school/classroom visits aimed to build familiarity, trust, and respectful, as well as to familiarize the researcher

The first meeting was the places where the teachers started to build their relationships and the meeting can enhance the co-teachers learn from each other regarding their PCK and practices as they related to Science subject. This meeting promotes co-teachers to have an opportunity to share teaching experiences, difficulties in PCK, and classroom contexts. For the first central meeting, we discussed about the research and how the co-teachers were going to achieve the goal of teaching Science using CTM. At the end of this meeting, the researcher discussed her role, co-teachers role, and a research educator role. In addition, the researcher explained the data collection methods and the timeline. The aims and procedures of the first meetings were.

First Central Meeting

Activity I: Understanding What CTM is

Describing the CTM mean and the role of co-teachers in this study, the researcher served as a facilitator and one of the co-teacher who is a CTM team member. Co-teachers observed the VDO of co-teaching and reflected what they thought on the co-teaching model of VDO. Activity I was designed to intensify the participant to understand CTM is one of long-term professional development program that the teachers should willing to participate and contribute time for CTM.

Activity II: Reflecting on Teacher's Understanding and Practice of PCK and Teaching Problems in Classroom

Activity II provided opportunities for the teachers to practice their written reflection on their teaching. During the researcher visit, the researcher observed the teachers' classrooms and talked informally to the teachers about several issues such as science teaching and learning, students' background, school, teachers' obligation, and teachers' background. The teachers were given a reflective protocol to guide their writings. The researcher then provided feedback on their writing. The reflective writing was about and how they understand and practiced PCK before they participated in the professional development experience from the CTM. In the middle of this month, the case study teachers were interviewed individually regarding, science teaching experience, prior understanding of PCK and their reasons and expectations for participating in the CTM. The interviewing process is described in the section of data collection. Individual co-teachers were asked about their prior knowledge. The co- teacher taught the lessons in their actual developing a lesson plan. The schedule of the school/classroom visits is in July- August 2009; the researcher began to assess what the teachers' understanding and practice of PCK by interview in August, October, and September 2009. The interview protocol is shown in Appendix B

CTM II: Preparation

In October 2009, the researcher began to assess what the teacher knew about, and how they understood and practiced of PCK focusing on inquiry based teaching and learning. The aims and procedures of the second central meetings were focusing on the essences of Thai education as it related to the Basic Education Curriculum and its National Science Curriculum Standards. Promoting elementary science teacher's awareness of educational goals makes them more aware of reformed teachers. The researcher, elementary science teachers, and science educator discussed and presented their ideas about educational issues regarding educational reformed outlined in the National Education Act B.E. 2542 (1999), Basic Education Curriculum B.E. 2544 (2001), and the National Science Curriculum Standards B.E. 2544 (2002) instead. These activities that are presented as below have aims to promote elementary science teachers to realize their roles and the values of themselves in educational reform. Especially, the activities' aims also focuses on developing of teachers' understanding and practice of PCK. The researcher used the problems or issues that elementary science teachers had in their classroom then reached to their needs for professional development. For second central meeting, the researcher provided research participants with eight activities.

Second Central Meeting

Activity I: Understanding What Teachers' Problems and Needs for Reformed Learning and Teaching

The activity was focused on the teachers' discussion of their problems or issues that they had to face in their classroom. This activity was conducted to enhance elementary science teachers' problems in aspects of PCK and what knowledge they need to develop including sharing teachers' background and classroom context. In order to get a good view of the participant and their classrooms regarding their educational backgrounds, classroom context, students' context, and school based curriculum in the upper elementary grade levels. The researcher would like to clarify brief details of the concept and procedures of the study. The main purposes of this meeting were to make commitments between research participants and researcher of their roles. In consideration of the elementary science teachers' workload and additional responsibilities in the school the researcher has to be considerate in making a plan and schedule for teachers. The plan should be very flexible for teachers.

Activity II: Learning the Importance of PCK and Generating the Components of PCK

The activity was focused on teachers' discussion about why we considered PCK an essential part of science teacher education. This allowed us to move on to consider the problems science teaching face by the bifurcation of content and pedagogy implicit in the standards and explicit in classroom practices. And finally we began to examine the assumptions of science, the science education community and the roles that PCK plays in this community. Group discussion was used to critiques the importance of PCK and generate the components of PCK. In sharing and discussing in this activity, the researcher provided questions for guiding the teachers to aspects of the essential components of PCK. The researcher also provided the NSCS documents for reviewing about standard expectations for science teachers to do and learner to learn.

Activity III: Learning the Importance of Inquiry Based Teaching and Generating the Essential Features of Inquiry Based Teaching

The main goal of an activity is promoting the elementary science teachers' awareness of the significance of teaching and learning science through inquiry. The researcher explained the purpose of the activity. After that she invited the teachers to share their ideas on what they believe with inquiry teaching on students' learning? The researcher then summarized elementary science teachers' ideas and provided them the NSCS documents (DCID, 2000). The teachers were assigned to analyze and share their thoughts with CTM members. In sharing and discussing this activity, the researcher used questions for guiding the teachers to create the essential features of inquiry based teaching in aspect of goals or purposes for teaching science, students and teacher role in inquiry -based classroom, and some important features of inquiry process such as students' interest and curiosity is an important aspect that teacher should use for starting the classroom. Moreover, the implicit purpose of this activity was to prepare the teachers for the further stage of CTM in which they were asked to share and create inquiry based lesson plans.

Activity IV: Reflecting on Teacher's Teaching VDO and Lesson Plan

The purpose of Activity V was: 1) sharing their teaching experiences, reflection, and difficulties in understanding and teaching inquiry-based teaching; 2) assisting and supporting each other in improving inquiry-based lessons; 3) learning PCK through reflection on their own instructions and communication with each other. At the beginning of the activity, the researcher informed teachers of the purposes of the activity. The researcher showed teachers' VDO teaching and their inquiry-based lesson plans via visualizer and LCD projector. These lesson plans were selected by the teachers independently. Grade 4 science teacher selected the lesson plan regarding food nutrient. Grade 5 science teacher choose topic of light and sound. The third science teacher who taught in grade 6 presented topic of Ecology. The researcher helped the CTM members understand the classroom context by showing pictures of the classrooms via LCD projector. After the presentation of each teacher's teaching, the teachers had chance to discuss and critique on their teaching and their lesson plans. The teachers reflected their teaching and lesson plans, provided suggestions, and support CTM team member success. These topics that were used in the discussion included: classroom context, goals or purposes for teaching science, science content, teaching strategy, learner and learning, science curriculum, and science learning assessment. In addition, this discussion also focused on the teacher role, the student role, and issues of concern.

After discussion of all teachers' teaching and lesson plans, the researcher asked the teachers to compare and contrast their lesson plans in order to seek out the essence of inquiry teaching and share their PCK. After discussion, the CTM members agreed to focus on PCK in aspect of understanding and practice of knowledge for setting goals or purposes for teaching science; understanding and practice of pedagogical knowledge; and understanding and practice of knowledge of context. The teachers had chance to select freedom on science topic that they had problems in their teaching for creating their lesson plans. The activity that the researcher used to promoting their PCK in the teachers' lesson plans is shown activity 5.

Activity V: Learning and Generating Lesson Plan

To develop the teacher lesson plans, this study was designed to give the teachers the freedom to selected science topic and create their own lesson plans with guidance and suggestions from the CTM members and educator. This was the starting point for teachers to begin to understand themselves as being good science teachers and how they can reach their teaching and learning goals or purposes for teaching science. Moreover, they also got chance to integrate their knowledge that they learnt from previous activities of CTM II. Individual teachers were given time to plan their teaching plans during October- November. After that the elementary science teachers and researcher who were in CTM member reflected on that lesson plans through CTM III: co-planning stage. To help teachers view science topics are interrelating with other science topics, teachers were given the opportunity to discuss and to analyze the science content together. This activity could be a guideline for teachers to use in the planning stage. Teachers used their own lesson plans to discuss in the third central meeting of CTM III: co-planning stage.

Activity VI: Learning the Importance of CTM and Generating the Essential of CTM and CTM's Processes.

To enhance elementary science teachers' understanding of CTM and its process is the main purpose of this activity. The researcher showed the teachers Co-teaching VDO via LCD projector. After that the CTM members were briefed following these guidelines: What are advantages and disadvantage of CTM? What are important factors that promote CTM success? What are essential of CTM; and How to be co-teacher in CTM processes? The teachers and researcher then summarized the answers of these questions. The researcher provided the teachers with documents regarding co-teaching model. At the end of this activity, the teachers knew that CTM is helpful, so you can identify where you are, the challenge you will face, and actions you can take to meet them to advance to the next stage and finally you can think –as-one. The teachers understood that they have participant in the three stages of CTM: co-planning; co-teaching; and co-evaluating. After the second central meeting, the research participants who were elementary science teachers in grade 4, 5, and 6 were ready to step forward into co-planning stage.

CTM III: Co-Planning Stage

After the co-teachers passed the stage of "getting-to-know-you" in which the co-teachers attempt to establish a new relationship- that of the co-teachers, the elementary science teachers who participate in CTM had chance getting to know himself or herself and their co-teaching partner from new perspective. After all of the activities of preparation stage, the co-teachers were given training by reflecting, sharing, and discussing their experience in teaching Science subject and their PCK. In co-planning stage, the third central meeting was conducted on weekday and weekend in December 2009. The objectives for the meeting were: 1) to assist and support each co-teacher in improving inquiry-based lessons; and 2) to provide the co-teachers with the opportunity to share and learn their PCK by the opening communication. From the second meeting, three elementary science teachers selected their own science topics that they had difficulty teaching in their classrooms for developing in the next stage

(Grade 4: Animal and Plant Behavior; Grade 5: Weather and Climate; and Grade 6 Electricity and Magnetism) . There were two activities that help the co-teachers to create and plan their inquiry-based lesson plans. After informing the teachers of the purpose of the third central meeting, the researcher introduced the activity to the CTM team.

Third Central Meeting

Activity I: Reflecting and Sharing of the Teachers' Lesson Plans

The Activity that was provided to the teachers of this meeting was to give opportunity for the teachers act as co-teachers. At the beginning of this activity each elementary science teachers worked as co-teacher with the researcher who also was one of the co-teacher of CTM. The co-teachers (teacher and researcher) reflected and discussed about their inquiry-based lesson plan after school time. Every Saturday in December 2009, the CTM members had a meeting for reflecting and discussing their inquiry-based lesson plans. The co-teachers presented their designed lesson plan to the CTM members. Descriptions of activities, questions, the students' worksheets, or assessment and evaluation techniques were provided to get a sense of their practices. The CTM members were asked to reflect and to make suggestions regarding the co-teachers' lesson plan. The co-teachers learnt how to improve their lesson plans during this valuable discussion time. Finally, the co-teachers got their complete lesson plans that they used in the activity II of the third central meeting.

Activity II: Microteaching with CTM

To prepare the co-teacher on how to implement their lesson plan, the process of microteaching was conducted to help the co-teachers seek new routes to transforming their lesson plans and practices when they implement them in class. The co-teachers act as team teaching that the co-teachers can support other during classroom teaching. This model involved both teachers taking a lead in active instructional responsibilities. In this co-teaching, both teachers together co-presented a lesson. Both teachers were viewed as equal partners in instructional planning and delivery. The co-teachers taught following their inquiry-based lesson plan. Other members of CTM were students and observers at the same time in microteaching classroom. At the end of this activity, the CTM member reflected and made suggestions on their implementing of inquiry-based lesson plan and their co-teaching.

Note: The first round of co-teaching module of activities I and II were focused on co-teaching between the elementary science teacher and researcher. The co-teachers selected one lesson plan using with reflecting and sharing of the teachers' lesson plans and microteaching. For the second round the co-teachers in this activity were working between two elementary science teachers who would like to work together with new lesson plan.

CTM IV: Co-Teaching and –Evaluating Stages

This stage is characterized by a "my-turn-your-turn" relationship. A "you teach this and I teach this" teaching arrangement was seen at this level. This stage the co-teachers participated and decided to divide teaching responsibilities, each taking charge of a certain curricular area. The co-teacher had opportunity to share their PCK in different experiences of teaching elementary Science subject. Professional communication was more expanded than in the beginning stage but not as fully established and interdependent as in the co-teaching and evaluating stage. The co-teachers had reflection and discussion after their classroom time. After that the CTM team reflected and discussed on each co-teaching via recording VDO every Saturday from January to March 2010. Each elementary science teacher had 6-7 times for co-teaching with others under the specific science topics.

Forth Central Meeting

Activity I: Reflecting and Evaluating on Co-Teachers' Teaching and Teacher's Learning in Aspects of PCK

The forth central meeting was the first time that co-teachers taught in the real classroom and they implemented their lesson plan in their own classroom. Both co-teachers also reflected on their teaching practices after implementing by completing assessment of co-teaching model. They were asked to share their experiences, problems, and student responses, development of PCK, and problem regarding their co-teaching a particular lesson via semi-structured interview by the researcher. Both co-teachers and the researcher had small meetings for sharing and discussing on the co-teachers' teaching practice after classroom time. Every Saturday during January-March 2010, three elementary science teachers and the researcher had chance to reflect and discuss on their co-teaching classrooms. The meeting was not just for the researcher to get information, but also an opportunity for each co-teacher to reflect their CTM members' responses and perhaps contribute further reflection. They discussed and analyzed each problem and proposed some recommendations to solve the problems by using their teaching experience. This was a rewarding time for co-teachers learning and sharing their knowledge in aspects of PCK.

Fifth Central Meeting

Activity I: Reflecting and Evaluating on CTM and Concluding What Teachers Learn from CTM in Aspects of PCK

To understand what the co-teachers think about CTM and what had they learnt from CTM in aspect of PCK were goals of this meeting. The researcher showed them the conclusion VDO of co-teaching model that they started to participate since early June 2009 until March 2010. The elementary science teachers were asked to discuss following these questions: 1) what did you think about advantages and disadvantage of CTM? ; 2) What do you want to change in CTM and Why? 3) what had you learnt from CTM in aspect of PCK? and 4) how the CTM enhanced you to develop your PCK? Discussion was used in this meeting.

In summary, the professional development program employed in this study encompassed a period of time of 1 year. The upper elementary science teachers learn to develop their PCK and they understand how to teach Science subject based on Constructivism. Especially, the teachers understand and practice more in inquiry base teaching and learning through the context of CTM. CTM team participated in one – to-one and central meeting and worked through CTM stages. A diagram of the CTM is provided in Figure 3.2. A schedule of all meetings with the teachers is displayed in Appendix C. A Description of activities and data collection for this study is shown in Appendix D.

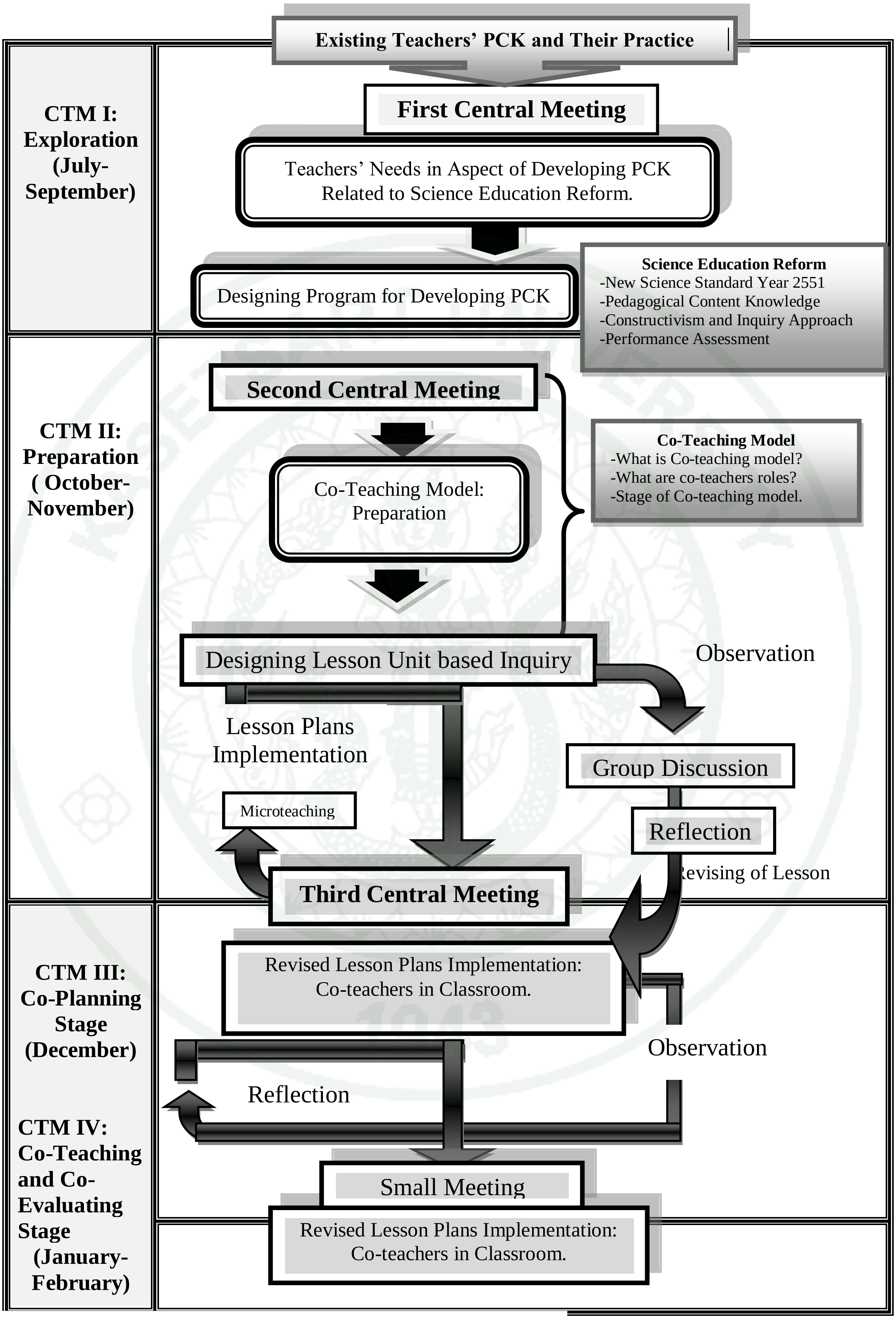

Figure 3.2 A Co-Teaching Model [CTM] Procedures

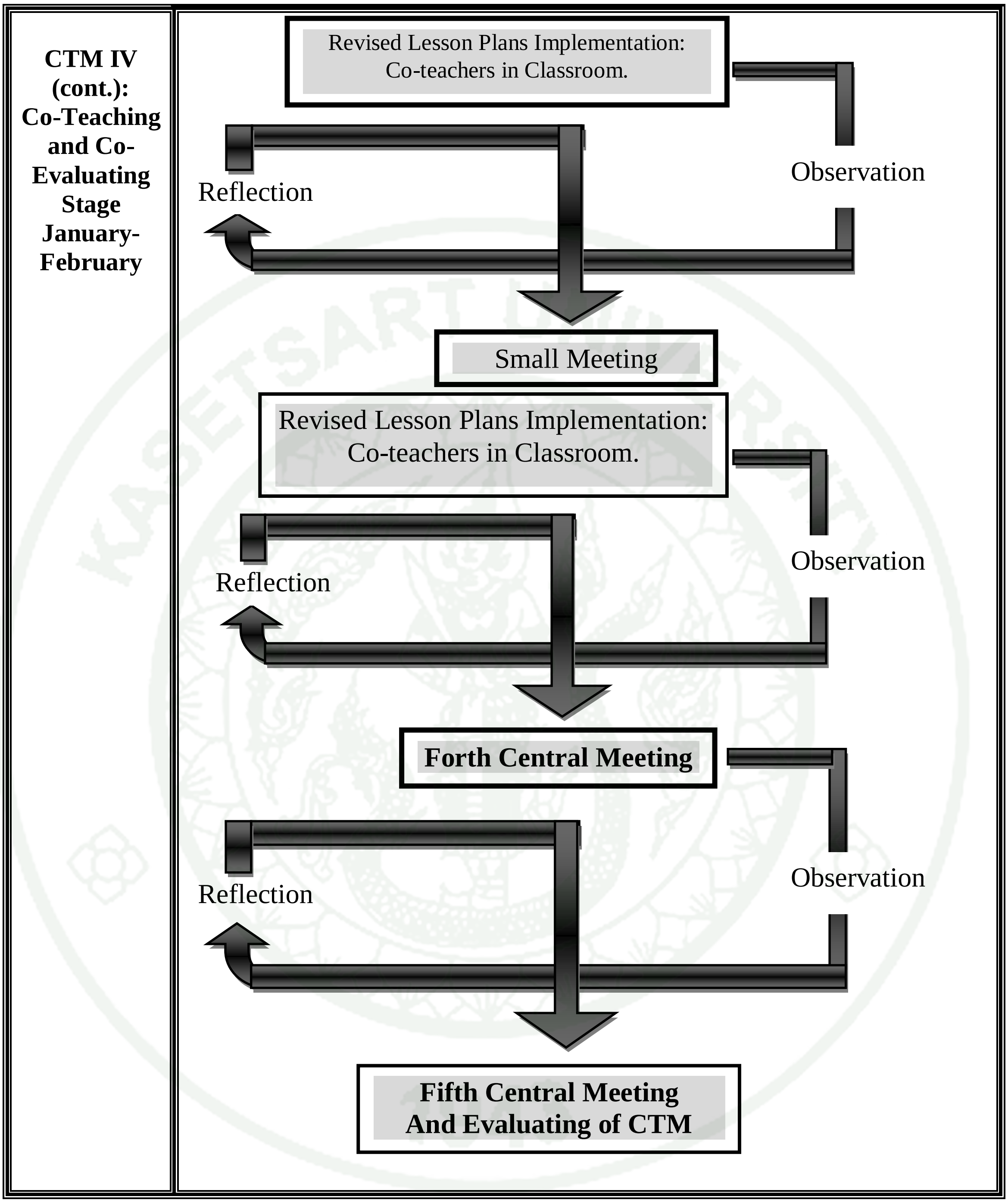

Figure 3.2 (Continued.)

Data Collection

In order to study the development of elementary science teachers' understanding of PCK and practice through CTM, multiple data sources have been used during the research process. Utilizing grounded theory in this research, the researcher used data from multi-sources to maximize flexibility and to help generate theory (Conrad, 1993). Using data from a variety of resources or using more than one method has provided a fuller understanding of this study for the researcher (Bogdan and Biklen, 2003). In interpretive case study, classroom observation, individual interview, questionnaire, inquiry based lesson plan, written reflection, and group discussion are preferred to assess all teachers' PCK with their thinking, actions, and reasons in the specific context and setting.

In the data analysis methods, the researcher attempted to find out patterns of growth or development by comparing the in-service teachers' understanding of PCK and practices through CTM, in both initial and final stages of the model using multiple sources of data. The approach to analysis involved an inductive process: categorical aggregation and a search for correspondence and patterns. Because this study employed a multiple case research design, the data analysis methods began with within-case analysis and followed by cross-case analysis. Triangulation was used to describe the idea that the researcher tried to construct an explanation by using more than one or multiple sources of data. The following topics discuss details of these six methods of data gathering. By using within-case analysis to investigate each in-service teacher's PCK development, the researcher transcribed and/or analyzed data of each data source as described below:

Classroom Observation

Qualitative observation occurs in a naturalistic setting without using predetermined categories of determined categories of measurement or response (Adler and Adler, 1994). Classroom observation is a research method that was used in the research study. Observation is regarded as a valuable method of data collection widely used in case study research and other types of interpretive research. The aims of conducted observations are to provide some knowledge of the context, activities, people's actions or behaviour, and perspectives. Observational data is what happens in natural situations (Cohen, *et al*., 2000; Lankshear and Knobel, 2004) and researchers are permitted to gain some insight into the perspectives of participants which they may not feel able to tell during interviews. Sometime interviewers cannot get some data from participants because they feel uncomfortable to talk or are not able to discuss about the topics. Therefore, the researchers use observational methods to get that data (Merriam, 1998; Cohen *et al*., 2000). To observe the class, the researcher had to define the role of the researcher in each observation. The researchers need to know how to collect observation data and what their roles are. Which observational categories that researcher should use with their data collection depends on what their research purposes are. Research purposes guide the observation techniques and researchers' roles. Many researchers used observation that they are participants in the setting studies (Patton, 1990; Bell, 1993; Lankshear and Knobel, 2004). There are two main types of observation, non-participant and participant observations. In non-participant observation, the researchers will not do activities with the participants. Sometimes this type of observation is called the "unobtrusive method" (Denzin, 1978). The observer sits at the back of the classroom setting and records teacher-student discourse by means of a structured set of observational strategies (Cohen *et al*., 2000). The researchers can save time and budget when they observe with non-participant type. They can concentrate on what they would like to observe aligned with their research purpose. However, the process of non-participant observation may affect the teachers' behaviours. The participants might change their behaviours when the observer sits at the back of the classroom.

The second technique is participant –observation or participant as observer (Crowson, 1993). The researcher is one of group members in the setting being studied (Cohen *et al*., 2000). The aim is to gain a close and intimate familiarity between the researcher and a given group of individuals and participants' practices through an intensive involvement with people in their natural environment, often though not always over an extended period of time. Data obtained through participant-observation serve as a check against participants' subjective reporting of what they believe and do. Participant observation is useful for gaining an understanding of the physical, social, cultural, and economic contexts in which study participants live; the relationships among and between people, contexts, ideas, norms, and events; and people's behaviors and activities. The researchers can get inside information from participants because they engage in the interaction with participants. In this role, a researchers work with participants during their daily work, but a researcher has to remember that the primary reason for being in the field is to observe, not to participate (Crowson, 1993). Field notes and video recording are used to increase the potential of collecting data. Bogdan and Biklen (2003) suggest that to provide convenience and fruitfulness of observation, the researcher should use instruments to record on a bulletin board, writing on the blackboard, the arrangement of furniture, and discussion in the class.

The main advantages of participant observation are that it allows the researcher to obtain a deeper and more experienced insight on the activities that the individuals of a society perform and the ways in which they think. However, there are disadvantages of participant observation. Sometimes, it is unwelcome by the society being studied, as they often feel disturbed and that the researcher is invading their privacy. Being too much of a participant will lead the researcher to change the action of the participants (Bogdan and Biklen, 2003). Moreover, when the researchers participate in the activities, they may lose sight of some interesting perspectives of the participants. In addition the researcher's bias is important to consider. There are researchers who point out that participant observation is a highly subjective, and therefore unreliable in nature (Banister *et al*., 1994; Merriam, 1998). Therefore, the researchers should know what their roles are when conducting participant-observation and the ways of data collection should align with research purposes as much as possible. Multiple ways for data collection can help to decrease the researchers' bias such as researchers may use video recording to overcome the observer's view of situations (Bell, 1993; Cohen *et al*., 2000).

According to Patton (2001), the focus of observation is dependent on the framework of the study. In this case, the researcher focuses on elementary science teacher's understanding of PCK and practice through the CTM. Therefore, the aspects of classroom observation are focused on:

a) The role of the teacher: Activity director, Facilitator, Guide, Motivator

b) The role of the student: Active investigator, Minds-on investigator

c) Instructional objective: Scientific knowledge, science process skills, scientific attitude

d) Instructional process: Classroom introduction (Prior knowledge, motivation, scientifically oriented question), Investigation (Scientific investigation, Data collection),

The classroom observations were conducted during teachers' practices and during the meetings. Each participant was observed twice a month during their teaching by the researcher, acting as a non-participant observer. The researcher made descriptive notes of the events, activities, and dialogues about what happened in the classroom. The lessons were recorded using videotape. By using the videotape recorder, the researcher could collect detailed data of their teaching practice. The researcher made observation notes using the field note table (see Appendix D).

Although observation can provide rich data of what happens in natural situations and in people, it cannot reach inside people's minds to see what they are thinking. Interview data can complement for the disadvantages of observation's weakness. The following topic therefore is on the interview technique.

Individual Interview

As the research project seeks to contribute to the cultivation of insight and understanding of the enterprise bargaining process at the school level, the decision as to who was interviewed was made according to the potential of individuals to illustrate what happened on the basis of their direct involvement, as identified by previous observations (O' Donoghue, 2007). The interview is a method of data collection which is aimed at investigating what is in a person's mind. It allows interviewers or researchers to understand participant's perspectives of topics focused on (Lincoln and Guba, 1985; Banister *et al*., 1994; Merriam, 1998). An interview is a purposeful conversation involved by two or more people (Bogdan and Biklen, 2003). The primary function of the interview within the research agenda is to reveal the informants' perspectives on their own roles, and their perspectives on the experiences encountered. It is therefore necessary to provide the opportunity for a discussion between interviewer and interviewee which moves beyond surface talk to a rich discussion of thoughts and feelings (Maykut and Morehouse, 1994). The specific encouraging process of verbal and non-verbal techniques is used to help interviewees produce elaborate and detailed answers (Rapley, 2004). The interviewer can motivate participants or interviewees to discuss their interpretations of the world in which they live and express how they regard situations from their own points of view (Cohen *et al*., 2000). Researchers have to identify which types of interview would be appropriate with research purposes and help them to get data that can answer the research questions. Interview techniques are classified based on an interview structure continuum: structured, semi-structured, and unstructured (Bell, 1993; Merriam, 1998; Bryman, 2001).

Merriam (1988) has identified three major variants of the interview: the highly structured, the semi-structured, and the unstructured. In its highly structured form, the interview questions as well as their order are predetermined, and it tends to be used when a large sample needs to be surveyed. At the opposite end of interview continuum is the unstructured format which is based on the assumption that informants can define the world in unique ways. It is therefore exploratory in its objectives and does not rely on a pre-prepared set of questions. A semi- structured approach, on the other hand, is also predicted on the epistemological assumption that there are multiple realities, but employs loosely defined questions for guidance during the conducting of the interview. Using this classification, it has been decided that the style of interview which is most appropriate for this study is a semi-structured one. Each technique has strengths and weaknesses and different types of interview are for specific research purposes. The structured interview has higher validity and reliability than other types of interview (Bryman, 2001). Moreover, the structured interview can help researchers to save time at the analysis stage and they can be sure all aspects are covered (Bell, 1993). However, the structured interview reduces flexibility and spontaneity. The researchers will not be allowed to access participants' perspectives and understandings (Patton, 1990; Freebody, 2003).

Many researchers use semi-structured interviews in qualitative research because the semi-structure interview is more flexible than other kinds of interview. It is situated between the individual in-depth interview and the quantitative interview with a standardized questionnaire. A list of questions or specific topics is prepared as an interview guide to make sure all relevant topics are covered. Those questions or topics may not follow exactly in the way outlined on the schedule (Bryman, 2001). The interviewers should adapt questions and words to be specific respondents in the context of the actual interview. Semi-structured interview typically refers to a context in which the interviewer has a series of questions that are in the general form of interview schedule but is able to vary the sequence of questions. The interviewer usually has some latitude to ask further questions in response to what are seen a significant replies (Bryman, 2001). Interviewing is an active process where the interviewer and interviewee through their relationship produce knowledge; therefore, the building of free conversation can help researchers to access more in-depth view of interviewee's perspectives than the structured interview. The limitation of the semi-structured interview is that it is time consuming (Freebody, 2003), interviewers' skills may not be very reliable, and it is difficult to exactly repeat a focused interview.

Unstructured interview typically has only a list of topics or issues, often called an interview guide, that are typically covered. This type of interview relies primarily on the spontaneous generation of questions in the natural flow of an interaction. The style of questioning is usually informal. The phrasing and sequencing of questions will vary from interview to interview. The unstructured or informal interview is very similar to ordinary conversation. It is particular useful when the researcher does not know much about a phenomenon (Lincoln and Guba, 1985). The respondent is asked with few questions and they can answer to the interviewer freely. Questions of the informal interview may change over time, and each new interview builds on those already completed, expanding information that was picked up previously, moving in new directions, and seeking elucidations and elaborations from various participants (; Patton, 1990; Freebody, 2003). The unstructured interview is appropriate when the interviewer wants to maintain maximum flexibility to be able to pursue questioning in whatever direction appears to be appropriate, depending on the information that emerges from observing a particular setting. Under these circumstances, it is not possible for the interviewer to have a predetermined set of questions. The advantage of this approach is that the interviewer is flexible and highly responsive to individual differences, situational changes, and emerging new information. But there is also the weakness regarding generating systematic data that is difficult and time consuming to classify and analyze (Goetz and LeCompte, 1984; Patton, 1987; 1990; Bell, 1993).

The research purposes are important to identify as to what types of interview techniques the researcher should use with data collection. Especially, the researcher should understand the strengths and weaknesses of each type of interview technique and know how to handle its drawbacks of technique. Moreover, personal bias is also a crucial aspect that the researcher should be aware of when using interview. It may have an effect on the interview data (Bell, 1993; Cohen *et al*., 2000).In the current study, semi-structured interview and interview about event (Card Sorting) were conducted with individual teachers on four separate occasions. The first interview was performed at the first central meeting of beginning of CTM. The second, third, forth, and fifth were employed after the teacher implemented their inquiry based lesson plans in the CTM III and IV to investigate development of teacher's understanding of PCK. The interviews were scheduled, conducted in Thai language with open-ended questions (see Appendix C) and the interviews were audio-taped and lasted approximately 45 minutes. All interviews were conducted at elementary science classroom. The data from the audiotape helped the researcher access in-depth data from participants and support classroom observation data. The first interview focused on four areas: 1) elementary science teacher understands of PCK and their practice; 2) current problems and needs for reformed teaching and learning; 3) current understanding and practice of inquiry based teaching and learning; and 4) the reasons and expectations for participating in the CTM. The second, third, and forth interviews emphasized on two areas: 1) elementary science teacher's understand of PCK and practice 2) what factors that obstruct or support the development of understanding of PCK and practice through the CTM. The fifth interview was conducted to focus only on teacher's reflection to the CTM. The interviews were transcribed verbatim and used as primary source of data for exploring the development of teacher's understanding of PCK and practice.

Questionnaire

The term survey frequently is used to describe research that involves administering questionnaires or interviews. The purpose of a survey is to use questionnaire or interviews to collect data from participants in a sample about their characteristics, experiences, and opinions in order to generalize the findings to a larger population. The aim of survey is to describe relevant characteristics of individuals, groups, or organizations (Green *et al*., 2006). Questionnaire and interviews are used extensively in educational research to collect information that is not directly observable. These data-collection methods typically inquire about the feeling, motivations, attitudes, accomplishments, and experiences of individuals. The questionnaires are defined as documents that ask the same questions of all individuals in the sample. Respondents record a written response to each questionnaire item, although tape-recorded responses are possible. The respondents typically control the data collection process: they can fill out the questionnaire at their convenience, answer the items in any order, and take more than one sitting to complete it, make marginal comments, skip questions, or give unique responses.

Questionnaires have two advantages over interviews for collecting research data: the cost of sampling respondents over a wide geographic area is lower, and the time required to collect the data typically is much less. Questionnaires, however, cannot probe deeply into respondents' opinions and feeling. Also, once the questionnaire has been distributed, it is not possible to modify the items, even though they may be unclear to some respondents (Gall *et al*., 1996).

The questionnaire is more commonly used in quantitative research, because it is a standardized, highly structured design. The interview is more commonly used in qualitative research, because it permits open-ended exploration of topics and elicits responses that are couched in the unique word of the respondents. However, both methods can be used in either type of research. Yin (1989), for example, recommends using both methods during case study research. For example, the researcher starts to study by questionnaire with a large number and then interviews a smaller number. Questionnaire data is used to purposive sample for interview. Some researchers develop a questionnaire before they have thoroughly considered what they hope to obtain from the results. It is important that the researchers define their research problems and list the specific objectives to be achieved by the questionnaire (Gall *et al*., 1996).

Inquiry -Base Lesson Plan

The other major technique which will be employed for data collection in this study is document analysis. Document review is another method of gathering which can overcome some limitations of interviews and observations. The researchers believe that all organizations leave trails composed of documents and records that trace their history and current status. Documents and records includes not only the typical paper products, such as memos, reports, and plans, but also computer files, tapes, and other artefacts. Goetz and Le Compte (1984) use the term ‘artefact’ to describe the assortment of written and symbolic records which have been kept by the participants in a group. Such artefacts, as Merriam (1998) has indicated, have both limitations and advantages. In view of the fact that they are generated independently of the research, artefacts can be fragmentary and may not fit the conceptual framework. However, their independence from the research agenda can also be considered an advantage because they are thereby non-reactive. As such, they are a product of a given context and are grounded in the real world. This characteristic makes it likely that an analysis of a diversity of artefacts will help.

Lesson planning is an activity that also has the potential to motivate in-service elementary teachers in thinking how to transform science content knowledge and make it accessible to a diverse group of students. It also can help the elementary teachers realize the integration and interrelationship of knowledge bases embedded in components of lesson plans. As a result, a key activity of the CTM was lesson planning for the teaching of a particular science topic. In the first central meeting of the CTM, the in-service elementary teachers were asked to choose science topics and then plan the lesson using their own ideas. Then they reflectively and critically discussed their understanding and problems in lesson planning. At the end of CTM, the in-service teachers were required to revise their lesson plans before using them in their microteaching.

Written Reflection

Reflection is a form of metacognition—thinking about thinking. It means looking back with new eyes in order to discover—in this case, looking back on their teaching and learning. Teacher's written is another method for data collection used in this study to gain more understands what CTM members learn by each other. Reflection is a crucial step that practitioners learn to solve their practical problems and refine their practice (Kemmis and Mc Taggert, 1998). Reflection on teaching has the potential to facilitate in-service teachers' PCK development. Through reflection, in-service teachers can clarify and confront their ideas, beliefs, and values about teaching and learning science. They may then become aware of, and in control of, what they are doing, and possibly change their personal beliefs and teaching practice. As a result, the in-service teachers in the CTM were provided with many opportunities for reflection on their teaching including reflection on the CTM, their own teaching, co-teacher's teaching, and upper elementary school teacher's teaching. To help them reflect on their teaching, the in-service elementary teachers watched videos of classroom teaching performance and participated classroom discussion of guided issues and questions. These issues included the development and integration of each knowledge base in lesson plans and teaching practice, the appropriateness of teaching strategies with science concept, strengths and weaknesses of teaching, and suggestions to improve better teaching.

Additionally, throughout the CTM, the in-service elementary teachers were encouraged to become reflective practitioners. They openly reflected on the co-teacher's teaching in their weekly journal entries. This reflection showed what they felt they had learned from each period activity, what they did not understand, and what else they would like to learn. This information was used to help the researcher understand the in-service elementary teachers' ideas, in order to improve further teaching and learning activities in the CTM. At the end of the PCK based CTM, the in-service teachers were asked to plan a lesson plan for teaching the same content as they planned in the first week. The lesson plans developed by each in-service teacher in the first week of the PCK based CTM were compare with the last lesson plan of their unit.

The in-service teachers recorded their reflections by reflective journals in which they prepared and taught in the classroom. Assignment worksheets assigned in the PCK based CTM, associated with PCK and its components were data sources. The researcher collected data that relates to in-service teachers' understanding of PCK development through lesson plans and worksheets. The in-service teachers' biographies and portfolios also were collected. The data from biography and portfolio includes the background of each participant, and any contexts related to the in-service teachers' learning. These data served to enrich the description of the context of this research. The gathered data from lesson plans, interviews, and observations were triangulated. These documents provided the researcher with data related to in-service teachers' understanding of PCK development and factors enhancing and hindering their PCK development.

Group Discussion

A co-teaching partnership is based on a spirit of equality. Years of teaching experience, degree, or age do not place one teacher in a higher position of authority over the other. Decisions are made mutually and are mutually agreed upon. Each teacher has an equal role in planning, executing, and evaluating the lesson. Therefore, practitioners' learning experiences are opened while they communicate with team members. In this study, practitioners' learning experiences are opened while they communicate with team members. The three sciences attended in the discussion of CTM in central meetings. Particularly, the first central meeting also invited science educator to discuss and be expert in lesson plan analyzing. During meetings, research participants brought their lesson plans, teaching materials, teaching experiences, problems/concerns of their teaching by confronted in understanding of each aspects of PCK to share with the CTM team. The CTM members critiqued components of inquiry based lesson plans; purpose for science teaching, science content, teaching process, teaching and learning assessment, and teaching material, provided suggestions to their colleague for improving their lessons, shared their ideas, and finally, summarized of what they learned regarding PCK through CTM. The five meetings were video recorded. The researcher transcribed relevant parts of conversations of the CTM members and used for tracking teacher's understanding of PCK and their practices with regarding to inquiry based teaching and learning after they engaged in the CTM.

For the basis of authenticity, credibility and accuracy, the interpretive researchers should identify and determine about the documents such as the document's origins, authors, and reasons for being written, and the context in which it was written (Bryman, 2001). In this study, either document data or field notes from interviews, classroom observation and interview transcriptions will be presented in the form of textual data. Content analysis is the main powerful way for analyzing these textual data.

Data Analysis

Communication content presents rich human experience and the causes and effects of human action. Data analysis, therefore, is an important process of making meaning of the data, because the meaning of data will be presented when researchers interpret and analyze them. This process involves organization, reduction, and interpretation of data that derive from observation, interview, survey, and document review (Merriam, 1998). Data analysis is a dynamic process, and researchers can move back and forth between concrete and abstract bits of data, between inductive and deductive, and between description and interpretation. The data analysis of interpretive qualitative-based research is an iterative process in which assertions and questions are derived or generated on basis of evidence, and evidence is defined in relation to assertions and questions. Qualitative data collection and analysis are simultaneous activities (Merriam, 1998; Patton, 2002). In the case that researchers find their data is imperfect and not enough to conclude and they want to get a deeper set of data, they can re-interview or observe again to achieve saturated information and a better understanding of that data (Patton, 1990).

There are varieties of data analysis strategies for qualitative researchers to interpret their data and understand the meaning of the data. Content analysis is a powerful way to analyze textual data. This strategy is based on an inductive process. There are sub-categories including discourse analysis of narrative structures and ethnography content analysis (Love, 2003). Review of several definitions which have appeared in the technical literature will serve to identify the major characteristics of content analysis. Systematic content analysis attempts to define more casual descriptions of the content, so as to know objectively the nature and relative strength of the stimuli applied to the reader or listener (Waples and Berelson, 1941). The results of content analysis state the frequency of occurrence of a sign or group of signs for each category in a classification scheme (Janis, 1943). The most common method of content analysis is the constant comparative method. The constant comparative method of data analysis is regarded to develop the mean of grounded theory that is appropriate with a particular context (Lincoln and Guba, 1985; Merriam, 1998). This study used grounded theory as an analytical framework and was mainly emphasizing discourse analysis which aimed to understand content, themes, structures, and underlying assumptions in the speaking and writing of people (Love, 2003).

The constant comparative method is concluded into four steps: comparing incidents applicable to each category; integrating categories and their properties; delimitating the theory; and, categories and their properties are reduced and refined. The first step is comparing incidents applicable to each category. At this stage, the researcher begins with a particular incident from an interview, observational field notes, or document. The researcher looks for indicators of categories in events and behaviours and coded themes on documents. These codes are needed to compare their consistencies, and differences, and the consistencies between codes reveal tentative categories, and a memo is written to describe properties of these categories. The second step is integrating categories and their properties. This step requires the researcher to compare incidents to initial versions of the rules or properties describing a category. The researcher consequently considers new incidents and makes judgments as to whether or not the new incident exhibits the category properties. The third step is delimiting the theory in which the researcher considers both parsimony and scope of categories. The saturation of categories, whether there is a new code related to the categories, needs to be focused. In the last step, categories and their properties are reduced and refined and then linked together to formulate a theory to explain the meaning data.

The primary goal of grounded theory is to generate theory inductively from data. The data analysis focused on assessing how elementary science teachers develop their pedagogical content knowledge through the co-teaching model. Case study research is focused to understand developing teachers' PCK. The researcher analyzed documents and underlying knowledge of participants in speaking and writing. Data from multiple sources such as teachers' journals and interviews; field notes and videotapes from observations and card sorting were analyzed by the process of open coding to get the transcripts from the first interview, observation, reflection and card sorting, developing initial categories of the participant's pedagogical content knowledge and their practice by inquiry. In developing categories, the researcher used a constant comparative method of analyzing multiple sources of data served to triangulate the data in order to increase trustworthiness of the research findings and assertions made. Data from teachers' journals and interviews, field notes and videotapes from classroom observations, videotaped transcriptions from group discussions, semi- structured interviews, and card sorting when using the CTM will be transcribed and developed to core categories of developing pedagogical content knowledge.

Trustworthiness of Data Collection and Analysis

The aim of trustworthiness is a qualitative inquiry is to support the argument that the inquiry's finding are worth paying attention to (Lincoln and Guba, 1985). This is quite different from the conventional experiment precedent of attempting to show validity, soundness, and significance. In any qualitative research project, four issues of trustworthiness demand attention: credibility, dependability, and confirmability.

The trustworthiness of data collection and analysis is discussed to present the quality of the research study. There are three main criteria of trustworthiness: internal validity, reliability, and external validity. Internal validity represents the explanation of a particular event (Cohen *et al*., 2000). Internal validity of interpretive research is focused on different issues from internal validity of quantitative research. In qualitative research, internal validity relates with the skill, competence, and rigor of the person gathering and analyzing data (Patton, 1990). Some researchers use credibility instead of internal validity (Lincoln and Guba, 1985). The strategies for enhancing credibility are prolonged engagement by investing sufficient time to reach purposes, persistent observation by identifying issues or elements that are most relevant to the problem, triangulation by using different sources, multiple methods of data collections, and multiple researchers, probing researchers' bias, establishing the adequacy of critiques written for evaluation purposes, and participants' checking of data collection and data analysis.

The second component of trustworthiness is reliability that refers to the extent to which research findings can be replicated (Merriam, 1998). In interpretive research, reliability is difficult to occur depending on conditions. Repeating the inquiry process can happen in qualitative research when it is under similar conditions and contexts. For interpretive study, the research tools and social context being studied may have changed over time. Reliability cannot be used with qualitative research, therefore interpretive researchers introduced the terms of dependability or consistency as a substitute for the traditional term (Cohen *et al*., 2000). This new term focuses on the consistency between research findings and data collection (Lincoln and Guba, 1985). To increase dependability, the researcher should describe and explain the assumption and theory behind the study, how data were collected in detail, how categories were derived, and how decisions were made throughout the inquiry (Merriam, 1998). Lincoln and Guba (1985) suggest that the process of data collection and analysis should be reviewed by auditors who will give the researcher feedback on their point of view of the accuracy.

External validity refers to generalization that relates with the degree that one research finding can be generalized to other studies. Generalizability in interpretive research is represented by transferability or comparability (Cohen *et al*., 2000; Lincoln and Guba, 1985). Transferability depends on the degree of similarity between the context of research being studied and the contexts of other research. Interpretive researchers have to provide a thick description to enhance transferability of research findings. Increasing transferability has to have rich and thick description that enables other researchers to determine how closely their situations and contexts and whether research results can be transferred (Lincoln and Guba, 1985; Merriam, 1998). The researchers that study with case study enhance transferability using cross-case analysis. The researchers can generate categories, themes, typologies or an integrated theoretical framework that can conceptualize and cover all the cases (Merriam, 1998). For this research, the strategies that the researcher used to ensure trustworthiness of data collection and analysis study are presented in the following topics;

Credibility

Credibility refers to the truthfulness of the data. It is enhanced when research activities are used which make it more likely that credible findings and interpretations will be produced (Lincoln and Guba, 1985). Credibility is also enhanced when strategies are put in place to check on the inquiry process and to allow for the direct testing of findings and interpretations by the human sources from which they have come.

The credibility for this study was enhanced by using multiple methods of data collection, prolonged engagement, and member checking. Multiple methods of data collection were the process of triangulation of data. The researcher gathered data from different sources. For example, lesson plans, field notes, observation transcripts, and interview transcripts were brought together and analyzed to examine participants' PCK. The data from different sources extend the understanding of teachers' knowledge and social contexts in different themes and perspectives. Prolonged engagement also enhanced credibility. The study covered one year, during which time the researcher was able to "get close to the data" and explore what really happened under engaging the co-teaching model. This prolonged engagement allowed the researcher to gain insights into the elementary science teachers' perspectives. After interviews, the researcher transcribed audiotapes and asked the elementary science teachers to check whether the data were correct. If elementary science teachers give some comments, the researcher noted their answers or perspectives.

Dependability

Dependability refers to the criterion of rigour related to the consistency of findings (Guba, 1981). The development of an 'audit trial' has become an accepted strategy for demonstrating the stability and tractability of data and the development of theory in qualitative studies (Donoghue, 2007).

Dependability was enhanced through working with the researcher and co-teachers. Because the researcher also acted as the co-teacher for the co-teaching model, some important activities or events might not have been observed. To deal with this concern, a co- teacher also observed in the same classroom during with the co-teaching model and described events or activities happening in the class. The descriptions from the co-teachers were compared with field notes from the researcher. The data from both increased the depth of observation by providing two perspectives. For all steps of data analysis, the researcher met with elementary science teachers to discuss and to gain consensus of findings. For example, videotape records were reviewed by the researcher and elementary science teachers. Then the researcher and the teachers discussed the assertions from data analysis. Where the researchers and teachers held different views of data, the researcher re-analyzed data and then discussed to obtain an agreement on finding.

Transferability

According to Lincoln and Guba (1985), transferability, in a strict sense, is impossible in qualitative inquiry; however, it is possible when operating in this paradigm to generate theories which incorporate working hypotheses together with descriptions of the time and context in which they were found to hold. If this incorporates appropriate thick description then judgments can be made about the possibility of transfer to other situations.

The transferability of this research is enhanced by providing the thick description and by the multiple case study design. Thick descriptions have been achieved by the researcher engaging in the co-teaching model for one year. The researcher can get close to variety of data about participants' perspectives and their contexts. These data enable other researchers or leaders to determine how their situations match this research situation, and whether findings of this study can be transferred. In this study, each case (participant) may have different perspectives and knowledge bases. However, because multiple case studies are the research design, common themes or integrated theoretical framework from all cases increase the transferability of the study.

CHAPTER IV

THREE CASE STUDIES OF IN-SERVICE ELEMENTARY SCIENCE TEACHERS' UNDERSTANDINGS AND PRACTICES OF PCK THROUGH A CO-TEACHING MODEL

Introduction

This chapter presents results of the three case study teachers who were teaching in elementary science at different grade levels. The results focused on the teachers' understandings and practices of PCK before and after they engaged in the CTM. The chapter aims to address the first and third research questions: What are the elementary science teachers' understandings and practices of PCK prior to participating in CTM? And what are some of the characteristics of the PCK developed by elementary science teachers when engaging with the CTM? The chapter begins with an explanation of the essential features of PCK which are used as a framework for the data analyses: this section is followed by each teacher's background information; the results of the teacher's prior understanding and practice regarding PCK before the CTM are then provided; and the elementary science teacher' development of understanding and practice of PCK. Throughout this chapter, pseudonyms are used to represent the case study teachers' names; these are Miss Malai, Miss Napaporn, and Mr. Sirod.

Essential Features of Pedagogical Content Knowledge

Pedagogical content knowledge [PCK] is a 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 student, 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. This knowledge is about how to teach particular content in particular ways resulting in 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 the teaching context, content and experience. Therefore, the aims for attempting to identify essential features of PCK are to guide the teachers to develop their knowledge for planning, implementing, observing, and reflecting upon their PCK and to provide the researcher a framework for conducting interviews, classroom observations, and data analyses. These essential features were derived from the PCK model initially proposed by Shuman (1986) and subsequently interpreted by Grossman (1990) and Magnusson *et al.* (1999). The researcher adapted these PCK models to be consistent with the goals of science teaching and learning in Thailand, the role of teachers and students in science classroom and the inquiry oriented activities suggested by the NSCS (DCID, 2002), the 5Es inquiry process guided in the Manual of Science Teaching and Learning (DCIC and IPST, 2002). A brief description of the essential features as they pertain to the context and subject matter of this study is displayed in Table 4.1.

Table 4.1 Essential Features of Pedagogical Content Knowledge

Essential Features of Pedagogical Content Knowledge		
Knowledge	**Aspect**	**Description**
Subject Matter knowledge		Science conception in Grade 4, 5, and 6 (Animal and Plant Behavior, Weather and Climate, and Electricity and Magnetism)
Pedagogical Knowledge	*Knowledge of Goals and Purpose for Teaching Science*	To learn scientific knowledge, science process skills and scientific attitudes in relation to the expected learning outcomes for 4th-6th grade students consistent with the NSCS (DCID, 2002; DCID and IPST, 2002)
	Knowledge of Instructional Strategies for Teaching Science	Strategies for specific science topics
Pedagogical Knowledge	*Knowledge of Instructional Strategies for Teaching Science*	Inquiry-based Teaching and Learning **Instructional Process** **Classroom Introduction** 1. Inquiry process begins with questions that students are interested in or curious about. 2. Inquiry process begins with scientifically oriented questions (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).

Table 4.1 (Continued)

Knowledge	Aspect	Description
Pedagogical Knowledge	*Knowledge of Instructional Strategies for Teaching Science*	**Investigation** 3. Scientifically oriented question is answered by scientific investigation. 4. Students, the teacher, or both parties designs an investigation. 5. Students conduct an investigation and collect data (DCID, 2002; DCID and IPST, 2002). **Conclusion/Explanation** 6. Students, the teacher, or both Parties analyze data gathered from an investigation. 7. Student formulates a conclusion/explanation from evidence and their prior knowledge to address the scientifically oriented question. 8. Students, the teacher, or both parties connect the conclusion/ explanation to scientific knowledge **Communication** 9. Students communicate and justify their conclusion/explanation with other students. 10. Students evaluate their conclusion/ explanation in the light of alternative ones, particularly those reflective scientific understanding (National Research Council, 2000; DCID, 2002; DCID and IPST, 2002).

Table 4.1 (Continued)

Knowledge	Aspect	Description
	Knowledge of Instructional Strategies for Teaching Science	**Group Work** 11. Students have a chance to learn through social interaction during group work. (DCID, 2002; DCID and IPST, 2002).
Pedagogical Knowledge	*Knowledge of Science Curriculum*	1. Knowledge of goals and objectives for the students in science subject including national- or school level document that outlines a framework for guiding decision making with respect to science curriculum and instruction. 2. Knowledge of the programs and materials that is relevant to teaching A particular domain of science and specific topics within that domain.
	Knowledge of Learner and Learning	1. Knowledge of requirements for learning refers to the prerequisite knowledge for learning specific scientific knowledge, as well as teacher's understanding of variations in students' approaches to learning as they relate to the development of knowledge within specific topic area. 2. Knowledge of areas of student difficulty and students' alternative conceptions refer to teachers' knowledge of the science concept or

Table 4.1 (Continued)

Knowledge	Aspect	Description
		topics that students find difficult to learn.
Pedagogical Knowledge	*Knowledge of Learner and Learning*	3. The role of a student in classroom: Active learner, active investigator, or minds- on investigation. The role of teacher in classroom: Active director, facilitator, guide, or motivator (DCID, 2002; DCID and IPST, 2002).
Knowledge of Context	*Community*	To understand and apply community context into classroom practice.
	School	To understand and apply school context into classroom practice.
	Student	To understand and apply students' background into classroom practice.

The report is presented by case study. There are three case study participants in the CTM. Malai, Napaporn, and Sirod are pseudonyms names for the three cases. Each case study is reported with the topics as displayed in following Table 4.2

Table 4.2 Conclusion of Topics for Reporting the Case Study's Understanding and Practice of PCK through CTM

Topic	Sub-Topics	Detail
Background Information		
Students' Backgrounds		
Classroom Context		
Case Study's Understanding and Practice of PCK before Participating in PCK-Based CTM	1. Understanding and Practice about Knowledge of Subject Matter	
	2. Understanding and Practice about Pedagogical Knowledge	2.1 Understanding and Practice about Knowledge of Goals and Purposes of Teaching Science
		2.2 Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science
		2.3 Understanding and Practice about Knowledge of Curriculum
		2.4 Understanding and Practice about Knowledge of Assessment in Science
		2.5 Understanding and Practice about Knowledge of Learner and learning
	3. Understanding and Practice about Knowledge of Context	
Case Study's Subsequence understanding and Practice of PCK after Participating in PCK-Based CTM	1. Subsequence understanding and Practice about Knowledge of Subject Matter	
	2. Subsequence Understanding and Practice about Pedagogical Knowledge	2.1 Subsequence Understanding and Practice about Knowledge of Goals and Purposes of Teaching Science
		2.2 Subsequence Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science
		2.3 Subsequence Understanding and Practice about Knowledge of Curriculum
		2.4 Subsequence Understanding and Practice about Knowledge of Assessment in Science
		2.5 Subsequence Understanding and Practice about Knowledge of Learner and learning
	3. Subsequence Understanding and Practice about Knowledge of Context	
***S*ummary of Case Study's Change of Understanding and Practice of PCK**		

The Case Study of Malai

Malai's Background Information

Malai was a 50 year old woman with 3 years of science teaching experience leading into the 2009 academic year. Malai taught at Wattanawan School, a public school which is funded by the government. She completed a Bachelor's degree of Social education and a master's degree in Educational Management from government universities in the province of Bangkok. She completed her master's degree three years before participating in this study.

In the 2009 academic year, Malai had 15 hours a week of teaching responsibility. She spent 12 hours teaching General Science in 4th grade. The remaining 3 hours were devoted to Food Club, Buddhism Club, Scouts, and classroom counseling. Malai indicated that her non-teaching assignments had often taken more time than her teaching responsibility. She also had the responsibility to do school accounting. During the past five year 5 years, Malai had attended several workshops provided by educational institutions and her school. These workshops focused on curriculum issues, lesson planning, use of instructional media, teaching method, science content and learning and teaching assessment. Malai said that most of these workshops were set on weekdays therefore she needed to leave her classroom with other teachers who were not science teachers (e.g., Thai Language teachers or Buddhism teacher). Malai always mentioned that she had to attend most of the workshops because the school principle assigned her to go. It was a requirement. In addition, Malai said that she had limited time for preparing her lesson plans and teaching. For school curriculum, her responsibility is only selecting the books and making lesson plans that are taught following the school curriculum.

In the first interview using card sorting (as described in Chapter 3), Malai picked a card that represented her primary teaching style. She taught science by having the students do activities and worksheets that she prepared for her students. The students read from a textbook and completed a worksheet. She also mentioned about teaching science by letting students do experiments. She gave the students instructions for the experiment first and the students then conducted explorations following her instruction, and finally the students wrote reports based on their findings. She lectured students before and after the experiments. In my classroom observations, Malai began her class with a discussion of the previous lesson concepts and activities and student assigned tasks. She started her lesson by lecturing the concepts that were taught from last class.

When coming to the PCK-based CTM, Malai expected to learn: teaching skills, examples of teaching strategies integrated with science content, teaching strategies that were student-directed and one of her objectives was to have the students apply their knowledge into their daily lives. Throughout the CTM, Malai was open-minded regarding her involvement in group discussion and her reflective entries in her journal. She often expressed her feelings directly to the CTM instructor and to her peers.

Students' Background

In this study, classroom observations were conducted with a class of 4th grade students. There were 35 students, comprised of 22 females and 13 males. Most of the students were from working-class families and lived residentially in the vicinity of school. Many of the students had an average to low achievement scores in science. The average grade was 2.5-3 while they were in 3rd grade.

In the first interview, Malai expressed her beliefs that her students lack basic knowledge. She also was concerned her students did not have scientific skills that were needed in her classroom. The students had less experience in science therefore Malai had problems when she had discussions with them. They could not share their thoughts and answers. Malai had to tell them the right answers and assigned them to record these answers to their notebooks. Malai believed that to be successful in learning science the students needed basic knowledge about the concepts of study and learning scientific skills. Most of the students in the classroom had financial problems. Parents could not provide enough materials for learning in science. As the result, Malai had to purchase teaching and learning materials for the students from her own personal budget. She revealed that she could not prepare the materials for every student.

From classroom observations, Malai and her students had a good relationship in and outside the classroom. She expressed that she viewed herself as students' friends. The students could come and consult with her anytime. She always used informal talking with the students in her classroom therefore they did not feel uncomfortable with her. Malai thought because of this kind of relationship, the students could talk openly with her. In addition, she mentioned that she was a very funny teacher so that is why the students liked to study Science in her class.

Classroom Context

In this study, the observations of Malai's instructional practices were conducted in classroom. The 4th graders' classroom was a middle sized room. The students' seats were organized in three columns. There was one blackboard and one white board permanently connected to the wall in front of the room. A teacher's desk was situated nearby the blackboard. Windows were located along the right side of the room. There were no decorations on the wall of both sides of the room. There was a television in the room, but it was never used for teaching. Three bookshelves filled with textbooks were placed in the back of the room. Items donated by the students and their parents were also placed in this area. There were two boards filled with announcements, students' works, and Thai festival pictures. During classroom observations, the researcher located herself to the back of the room close to the window. A layout of Ms. Malai's classroom is displayed in Figure 4.1

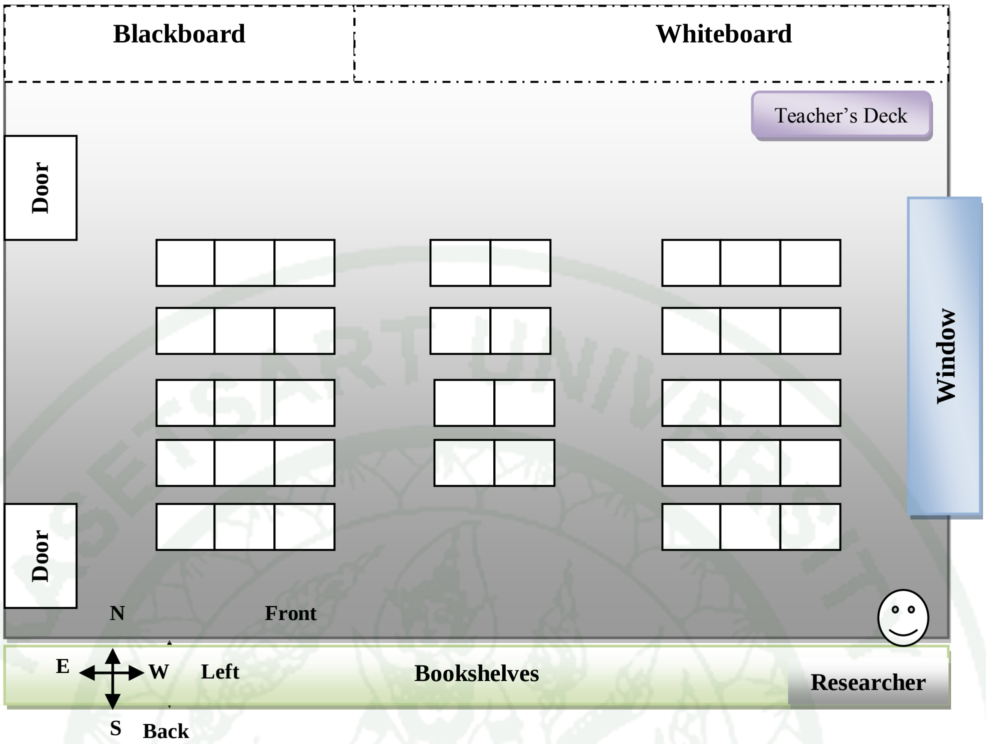

Figure 4.1 Layout of Malai's Classroom in 4th Grade

Malai's Understanding and Practice of PCK Before Participating in PCK-based CTM

This section presents results from the exploration (CTM I) and the preparation phase (CTM II). Prior to the CTM project the researcher interviewed three teachers individually regarding his/her understanding and practice of PCK. Also each teacher was observed by the researcher in their classroom as they taught inquiry-based lesson plans created on his/her initial understanding of inquiry-based teaching and learning. The classes were video-recorded. Malai's unit was Food and Nutrients and her lesson plans were: 1) Food and Nutrients; 2) Food Classification; 3) Nutrients and Energy; and 4) Food Contamination. After each lesson I the teachers to write a reflection on his/her lesson plans and teaching experiences to share and discuss with the CTM team in the first central meeting (Activity II) at Kasetsart University. Malai's prior understanding and practice of PCK was analyzed from multiple data sources individual interviews: card sorting, classroom observations, teachers' written reflections, teacher's initial inquiry-based lesson plans, and the first central meeting.

The prior understanding and practice of PCK is expressed according to the three main essential features of PCK.

1. Malai's Understanding and Practice about Knowledge of Subject Matter

Inadequate Background Knowledge in Science Subject is One Reason for the Lack of Confident in Teaching Science

In my first observation of Malai's class she expressed her feeling of being uncomfortable about science content in topic of food and nutrients. Many times she was not sure of her answers and she then walked to open her manual books to confirm that the answers were correct.

An example of this uncertainty appeared in a class presentation where students had categorized groups of nutrients in their favorite food. Students were randomly selected to present their task in front of class.

Students: My mom always cooks fried vegetables with tofu so I should get vitamins from vegetables.

Malai: Is it only vitamins in your food? How about tofu?

Students: Sorry, I do not know.

Malai: Tofu contains lots Carbohydrate that is used for body growth

Students: My dad tells me that if I eat tofu every meal, I might be tall

Students: In your reading sheet, tofu was high in protein?

Malai: OK, please wait let me check.

(Narration: The teacher walked to her deck and started to read her textbook.)

Malai: From reading sheets, OK, tofu has essential protein because it was made from soy.

(Malai's Classroom Observation 3#: August, 2009)

From Malai’s perspective, she believed that her ability to teach science concepts would be better if she knew more science knowledge. She said that she had different feelings when she was teaching her Social Studies subject class where she felt more comfortable. In the interviews before Malai participated in CTM, she commented: “Every time I taught a new unit of science with the first classroom, I did not feel comfortable with my knowledge in that subject. I liked to create reading sheets and worksheets for students because students would get a complete knowledge. It was better than if I gave wrong concepts to them. I knew that I was not good in science. But for the second class, I felt better because I remembered teaching knowledge and how to conduct activity from the previous class” Malai showed the researcher her textbooks that she used to prepare her lessons and to refer content in these textbooks for teaching.

Textbooks as Major Sources for Teacher’s Subject Matter Knowledge

Malai understood that she should teach the science concepts indicated in curriculum. Students should understand these concepts and know how to use scientific skills. Consequently, Malai tried to cover every science topic for them in her instructional practice. How did she lean science content? This question was interesting because she did not have background in science. Malai stated that every new semester was challenge to her to find good textbooks that could cover the science topics in the science curriculum standard.

2. Malai’s Understanding and Practice about Pedagogical Knowledge

To present this section, Malai’s understanding and practice about pedagogical knowledge were analyzed according to the PCK five sub topics of understanding and practice in: knowledge of goals and purpose for teaching science; knowledge of instructional strategies for teaching science; knowledge of assessment in science; knowledge of learner and learning; and knowledge of curriculum.

2.1 Understanding and Practice about Knowledge of Goal and Purpose of Teaching Science

Initially, Malai Holds Both Constructivist and Positivist Understanding of the Goal and Purpose of Teaching Science

In the first period of the CTM, Malai was asked what she expected her students learn and get after class. She said that the most important goal for her was helping students understand science content and get high scores on national examinations. Malai always presented information, generally through lecture or discussion, and questions and expected her students to learn these facts. At the start of most of her lessons, Malai told her students what science concepts they would learn in this period. She wrote these science concepts on the blackboard and expected the students to remember the concepts for answering the questions in Malai's worksheet. On these worksheets, she included example questions from previous national examinations.

> … I would be proud of my students if they have good understanding of science content and they could answer every question in my classroom. Especially, they could get high score in science from school test for their opportunities in higher education.
>
> (Malai's Interview#1: July, 2009)

From Malai's previous statement it shows that she has an obligation to uphold students' excellence for higher education therefore, she needs to teach or support her students in ways that promotes students' abilities for school test and the National Standard Test. In addition, she stated that when students understand science content, they could know how to use scientific skills and to understand nature of science. Malai explained her understanding about the nature of science and she mentioned three aspects: the definition of science, the characteristics of scientists, and the interaction of science-technology-society. For example, Malai agreed that science can be knowledge such as, principles, laws, and theories that explain the world around us, because science is something that can reasonably explain natural phenomena. At the same time, she explained science is also a searching tool for knowledge and for solving problems. On the other hand, Malai held positivist views about the nature of the scientific approach to gaining knowledge. She thought that the scientific method consisted of only one approach for acquiring the knowledge. This method needs to be a step-by-step process in which the first step is making observations.

Affective Domain Goals Hold a Prominent Position, but Not Always Central Goal

Malai's understanding and practices about goals and purposes for teaching science were consistent with contemporary constructivist views. She believed that a successful outcome of science teaching involved students using science concepts to explain natural phenomena in their daily life. In her responses in the card sorting, she stated that:

> …Science helps us to understand the world…After students understand what happen, how it happens, and why it has to be from science concepts, they can use these concepts in their daily life. The Students can learn from things around them in their daily life. Science learning is learning from phenomena happening in daily life and environment around us. They can use science to maintain environment as well.
>
> (Malai's Card Sorting #1: July, 2009)

In her lesson plans, she did not identify any affective goals. Malai thought that students can learn science content from school teachers, media, such as radio and television, and talking to other people. Her peripheral goals for learning science were to understand and explain natural phenomena, and gain scientific knowledge, and to apply and use it in a positive way. To meet these goals, she thought that a school teacher should be a guide who planned and organized learning activities for students. Activities should give students the chance to learn by themselves and engage with real things. The teacher should develop instructional media, such as models to help students see and imagine what happens in natural phenomena.

2.2 Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science

Malai was concerned with designing and organizing activities concerned with content. At the beginning of the CTM, Malai was asked to choose a unit of science to teach. She chose the food and nutrient concept for 4th graders. From her reflective journal, Malai expressed that she struggled with thinking how to sequence the learning activities. She commented that she would like her students to gain complete science content. As a consequence, her teaching activities relied on a didactic orientation (Magnusson, Krajcik and Borko, 1999) which often involved delivering content to students in a lecture style format.

Classroom Lesson Introduction: Teacher Uses Students' Daily Lives to Motivate Students' Curiosities.

In her lesson plan, Malai began with a discussion of students' daily life. Then she explained the importance of the food and food nutrients. Malai believed a teacher should begin an inquiry-based lesson by motivating students' interest. As Malai stated, "I always motivate students' curiosity when I start my lesson. I like to create teaching mediums such as pictures, models, or graphs (Malai's Interview#1: July, 2009). Data from lesson plans showed that Malai always used interesting pictures, things, and graphs to motivate students' interest at the beginning of each of her lessons. She used yes-no questions to ask students and sometimes when the students could not answers her questions, Malai delivered the right answers for students. Malai starts her lesson by questioning, but not linking students' interest to scientifically oriented questions. She did not probe her students' prior knowledge of the food and nutrients. Malai's teaching indicates that she realized that motivating students to have curiosity before starting her teaching is a major factor to help her reaching her teaching goals. After that she assigned the students to read from their textbooks and completed questions from her worksheets. Malai called students by their names to share their answers in front of the class. She then discussed the conclusions with the students from the first lesson. For second lesson, she motivated the students by dropping Iodine solution on a potato. She then discussed the observation with students. She expected the students to learn the concept by listening to her explanation.

Investigation: Focusing Hands-on Experiments, but Activities Are Directed by Teacher

Even though her understanding and practices were broadly consistent with contemporary constructivist views of teaching and learning science, the words "student-centered" and "constructivist-based teaching and learning" were new to her. Malai often expressed the feeling that she was curious about what teaching based on student-centered teaching actually looked like. She felt that a "student-centered" learning activity was when a teacher gave students freedom to do or learn anything they wanted. With respect to Malai's understanding of student-centered teaching, she thought students should acquire knowledge through hands-on investigation. She believed that when the students had an opportunity to conduct an experiment, they would learn science through student-centered approach. As Malai stated, "I thought students can learn science when they investigated with hands-on activity. Therefore, my lesson focused on giving chances for the students do experiments. I believed that students could link science concepts to understand phenomena if I could teach science using inquiry approach appropriately." (Malai's Interview# 1: June, 2009). Malai's lesson plan and her reflective journal, would suggest that the relationship between her understanding and practice of pedagogy are in a contradictory way. Even though she believed in constructivism, the way she thought students learned best was through teacher-directed set procedures. In her constructivist view, students learn by constructing their own knowledge from investigation. Malai believed in hands-on activities; however all the investigations were designed by the teacher and consisted of a set of fixed procedures. Students were assigned to follow the teacher's investigational procedures in worksheets.

She mentioned that when the students investigated and made conclusions that related to the science concepts being studied, then, she was successful in teaching science. In addition, she thought learning with happiness and a good relationship between teacher and students were key aspects of student-centered learning. (Malai's reflection#1: June, 2009)

Using textbooks and worksheets as the main teaching and learning material in the lesson. Malai liked to assign students to read science content from textbooks and the students answered questions in Malai's worksheets. Textbooks and worksheets were major tools for teaching science. Most of worksheets that she used in her classroom were copied from science activity books produced by private companies. Some worksheets and reading sheets, Malai developed from the materials she got from attending workshops. The students were given the worksheets at the beginning of the class to complete individually. At the end, Malai assigned students to discuss their answers in group discussion. After that she collected these worksheets for assessing and evaluating. Malai returned the worksheets to students the next class. The worksheets were recoding sheets. The students were required to record information or data that they learned in the class and they then answered the short-answer questions. The worksheets rarely asked the students to interconnect other scientific knowledge and to apply the knowledge in their daily lives.

Conclusion/ Explanation: Teacher Makes Conclusions for Students even though it should be Students' Responsibility to Do.

Malai realized when students could formulate conclusions to explain their experiments or phenomena, they learn science knowledge. Most of Malai's teaching was very teacher-directed with the students only participating by presenting their data. She asked the students to follow her instructions step-by-step to reach the conclusions that related to science concepts. She then led the discussion on recording data that the students presented in front of class and analyzed and formulated conclusions from students' data. When Malai attempted to discuss these results with her students, she always met silence in the classroom. She then asked students Yes-No questions. If the students answered correctly, she started to ask the next question without discussion of the reasons. She did not encourage students to express why they agree or disagree with the questions. Quite often she started classroom discussion while some students were still working on completing their worksheets. (Malai's field note#2: July, 2009)

From the reflective journal Malai stated that she knew her students could not analyze data and formulate conclusions on their own. She needed to help them by leading a discussion.

> …I believe that if I let them to discuss by themselves and make their conclusions on their own way, they would not reach to expectations that I set for my teaching objectives. When the students analyze data and make conclusions, they just give me raw data. It is not a conclusion that relates to science concepts. Therefore, I have to help them to know important aspects of data and discuss these aspects. Sometime I do not have high skills to do an experiment but I do need to teach students to use science equipment. I have to teach them to follow instruction from manual books.
>
> (Malai's Interview#2: July, 2009)

Communication: Students Only Present Their Data to Others, No Discussion Between Students.

To learn more scientific knowledge, Malai understood that students should share their ideas in class. She expressed that interactive discussion was an integral part of the prediction and explanation stages. Students learned from each other. As Malai mentioned,

> … In my class, my students always work as a group and they do experiments or studies together. At the end of teaching activities, they are required to present their data and conclusions. Students and me always discuss about the data and formulate conclusions. We find that some groups have different data

from others. One group says that their potato 's color is blue and other say that maybe you drop not enough iodine solution so why your group can not get purple……I am not sure what I should explain to them so I just say to them that both are the same results that explain the potatoes contain lots carbohydrate. After this class, I have to go and search information why this test has variation of color changing. Not only students learn, I also learn from them as well.

(Malai's central meeting# 2: July, 2009)

In Malai's practice, Malai provided the analysis and conclusions herself and did not allow the students to do this.

Malai: Did potato change its color?

Students: Yes, it did

Malai: What is color on your potato now?

Student: Purple.

Malai: Could you write your data on a blackboard? Thank you

Malai: So, from the data that are on blackboard, we can conclude that potato contains lots of carbohydrate when we drop Iodine's solution, it changes color of potato from white-yellow to purple. Please write this conclusion into your notebook and at the end of class, hand your notebook to me. I will check it and return to you on next class.

(Malai's Classroom Observation# 2: July, 2009)

The data showed that although students had chances to share their data, they did not have an opportunity to present a conclusion. As Malai reflected "My students always shared only their data and do not present their conclusion. They always waited me to write the conclusion on a blackboard. If I have to wait students to make conclusion, I would not finish my class on time. (Malai's Interview# 2: July, 2009). When a student brought an important but unrelated point to Malai's lesson plan, she did not ask the student to explain or to wait until after the current discussion finished. Students were not asked to agree or disagree with other students' ideas and reasons. Malai believed in students' learning science through classroom discussion, communication, justify, and evaluation, but in her practice, students still only reported what they had found.

Group Work: Students Have Their Own Responsibility for Cooperatively Working, but Only 1-2 Persons Do and Finish the Work.

Malai understood that students should learn together in a group. Malai thought that every student in group should know what their roles are. In her worksheets, students had to fill their name and their roles in the group. Malai perceived that in doing group science work it was helping students know how scientists work and how they found scientific knowledge (Malai's Interview 1# June, 2009). In group working, she mentioned that students were involved in setting hypothesis, doing experiments, observing, collecting data, formulating conclusions and reporting their results. From Malai's lesson plan data showed that each group was 5-6 students of mixed-gender and ability because she thought when students work with others students that were good friends; they could work together very well. However, the students were grouped by the teacher. As Malai stated,

> …I would rather my students set their own groups and they could selected to stay with others who are good friends than I group them without their input. I thought 5-6 students per group were appropriate for them to work and share their ideas together. I do not like to cluster them by score. I think when various abilities of students work tighter, they can help each other.
>
> (Malai's Interview 1# July, 2009).

With regard to Malai's teaching practice, the data showed that her classroom was different from her plans. She provided students the opportunity to learn in groups. As previous description, she assigned students to choose their roles and duties for working in groups. In practice, each group's members conducted experiments, observed, and recorded data individually. Only 1-2 active students per group worked on teacher's assignment. Other members talked and copied data from the active students. The teacher did not explain how group member should work cooperatively and she did not pay attention on each group when they were working.

2.3 Understanding and Practice about Knowledge of Science Curriculum

Science Curriculum Standard as Teaching and Learning Framework, Not School-based Curriculum

In the second and third weeks of the CTM I, the elementary science teachers including Malai were asked by researcher how science curriculum was important for preparing teaching. As Malai explained,

> …I study the curriculum document in detail to find out what topics are in each unit that I need to teach and to cover complete science concepts. I trust to use science curriculum standard provided by IPST more than school-based curriculum because I would like to make sure that my students learn and cover every science topic that is in the curriculum. When they go and take examinations, they would not have any problem with the content. In addition, I chose textbooks for teaching and created students' worksheets that had topics related to the curriculum.
>
> (Malai's Interview 1# July, 2009).

From the first central meeting we discussed the National Education Act 1999, the Basic Education Curriculum, and the Science Curriculum Framework. Prior to the meeting discussion, Malai thought that there was nothing new for her when she read the National Education Act. She commented that "after reading the act I think all things written in this document are what I knew before. She commented that the content in the Science Curriculum Framework were very broad and general. Most people might understand content, but still did not know how to bring this into a real classroom practice**.** Malai stated that she always used science curriculum standard as framework to know what science concepts that she had to teach to 4th graders. She referred to school-based curriculum that she had never used it for preparing her teaching. She trusted with the SCS more than the School-based Curriculum.

Focusing More Likely on Intradisciplinary on Science Content Knowledge

Malai understood that students should learn interconnections among science concepts that she taught. She mentioned that every science concept can link to other concepts. In terms of integration within science, Malai integrated concepts of food and nutrients with human body systems including teaching food nutrients with the concept of digestive system and the senses. As Malai explain in individual interview,

> …For example, in concepts of food and nutrients, I plan to teach students to know major food nutrients, the different ways in which the body uses nutrients, how nutrients in food are transported throughout the body, and the main function of the following parts of the digestive system: teeth, saliva, tongue, esophagus, stomach, intestines. I think when I teach students connected science concepts, students can apply to use in their daily lives.
>
> (Malai's Interview 2# July, 2009).

However, in her practice, Malai did not teach students to understand concepts of digestive system. She did not connect the concepts of food nutrients to any other science concepts. She said that she did not have enough time to teach extra science concepts in her classroom.

Malai did mention that she did not have a very good knowledge base in Science. When she prepared her lesson plans, she had to read from many textbooks to understand the science concepts. Some concepts she could not understand and she did not know how to represent them to her students, except through lecture. From previous conversations with Malai, it was clear that Malai did not connect the science concepts to other subjects such as Mathematics, Language, or Literature.

2.4 Understanding and Practice about Knowledge of Assessment in Science

Paper –and Pencil Tests as Major Assessments Tools for Learner's Learning in Science Subject

Initially, Malai focused only on student conceptual knowledge as the learning outcomes. In her first lesson plan about the food and food nutrients, she wanted her students be able to: explain the meaning of nutrients, major groups of nutrients, and the importance of nutrition to good health. Even though these learning outcomes were specific, they did not cover other dimensions of student learning such as science process skills, scientific attitudes, and attitudes towards science. To assess these learning outcomes, Malai employed broad assessment methods. Paper-and-pencil tests were utilized to assess the students' understanding of food and nutrient's conception. She conducted these tests prior to and at the end of the unit. Malai used the same test to measure students' understanding of food and nutrients. Then the pre and post-test scores were compared and this difference was used as indicator of students' learning. In addition, Malai made observations of students' answering questions, and checked their homework, to assess students' understanding. She did not use these assessment results to improve her teaching. As Malai stated "It is easy to know whether my teaching is successful or not from checking students' score. I always used multiple choice tests to assess students 'development in learning science (Malai's Reflective Written 2# July, 2009). Malai did not indicate any details of these methods such as when these methods were employed, and what concepts were assessed by these methods.

Worksheets as the Major Assessment Method for Knowing What Students Learn from the Classroom

Malai recognized that assessment of learner's learning was important process that every teacher should think about. The classroom observations show that Malai's major method of assessing was checking students' worksheets completed by students every class. Students had to hand their worksheets to her at the end of class. Malai returned these worksheets back to students in next class. She did not use any scale to evaluate student's learning. She just gave score of zero for not handing one in and 5 points for handing in their worksheets. She stated that when she read students' worksheets, she would know more about her student's learning.

2.5 Understanding and Practice about Knowledge of Learner and Learning

Probing Students' Prior Knowledge by Multiple Choice Test, but Not Really for Understanding and Using in Classroom Teaching

During the interviews, Malai presented her understanding about student prior knowledge that was an important component of teaching science. Students should be explored what their understanding of the science concepts that the teacher would teach. Malai's understanding revealed that she realized student's prior knowledge was important to her teaching and learning goals. However, Malai's understanding was not aligned with her practice. In her first lesson plan, Malai did not elicit the student prior knowledge in teaching about the food and nutrient concepts. In her third lesson, Malai provided students worksheets and assigned students to do activity. Students had to cluster the examples of foods into groups of high energy foods and non-energy foods. In her understanding and practice, Malai understood that students could present their prior knowledge by doing paper-pencil test.

Malai: Good morning, today we will learn about food and energy. I have reading sheets and worksheets for you. After you get it please read information from reading sheet first and you then do an activity I.

Students: What kind of energy in foods?

Malai: Energy is in food nutrients such as Carbohydrate, Lipid, and Protein

Malai: Before you start to do the activity. I would like you do pre-test for me. You have 10 minutes to fill this test. When you finish test, please hand it to me and you then pick reading sheets and worksheets on my deck.

(Malai's Classroom Observation 3# August, 2009).

The students were given these tests at the beginning of each class with a short amount of time in which to complete them. Malai did not identify what students' prior knowledge and students' alternative conceptions were. She delivered new science concepts to students and finally Malai understood that her students held science concepts. As Malai said "I used multiple choice tests to probe students' understanding of previous conceptions of food and nutrients. If my students' score are low, I will give them a tutoring class that will repeat the previous lesson briefly. I did not use diagnostic tests because I do not know how to analyze these tests and I do not have enough time to use in classroom. (Malai's Individual Interview 3# August, 2009). Time constraints and limited use of assessment are majors' factors influencing Malai's practice. All of her initial inquiry-based lesson plans did not have any activities to diagnose students' prior knowledge and students' alternative conceptions.

An Actively Director and a Lecturer Are Initial the Teacher's Role

From the first interview, Malai understood that teaching and learning through an inquiry approach involves her acting like a guide and a monitor. She said that the teacher should persuade, guide, and motivate students to gain knowledge by interesting activities or colorful media. The teacher's role should be encourager who leads students to think step by step. Students learn science more when a teacher motivates them to pay more attention on doing science. With regarding to Malai's teaching, it showed that her understanding in teacher's role is contradictory with her practice. In classroom observations, Malai used roles of director and lecturer more often than guide and motivator. Data from classroom observations illustrated that Malai directed students to do her activities in worksheets and guided students to formulate hypotheses, do experiments, collect data, and formulate conclusions. From classroom observation, Malai understood and taught students to learn science by doing and she acted as helper who could tell them how to do and explain why it happens. In the lessons, Malai always assigned students to read from her reading sheets to get ideas and she then explain the concepts at the end of class.

Students Are Active Investigators, but Base on the Instruction and Follow Lecturing

Malai noted that the role of learner should be active learner and investigator in inquiry-based teaching and learning. She expressed her view on teaching and learning in the interview that her class was based on Hand-on activities. She believed that students could construct knowledge through activities by conducting an experiment. As Malai mentioned "I think students should experiment using materials that the teacher prepared for them" (Malai's Interview 1# July, 2009).

Hand-on investigations were used in Malai's classroom. She encouraged her students to develop skills for inquiry such as observing, classifying, investigating, recording, and making conclusion. Malai did not really mention about scientifically oriented question that students should address the questions by themselves. In four lessons, she did not present that her teaching focused on students learning as Mind-on investigating. She started and ended her class without helping students to connect explanations from experiments to students' prior knowledge. In practice, students only remembered the concepts presented to them by the teacher.

Their learning occurred when definitions were memorized without stopping to consider.

3. Malai's Understanding and Practice about Knowledge of Context

Malai indicated that good science teachers should understand the community, school, and students' background – that is, the context in which their teaching occurs. Students' backgrounds were different and their abilities to learn science were varied. Malai also commented on her understanding of the community. She used to bring students to the temple for studying concepts of living things and non-living things. As Malai mentioned,

> …Students have more interesting feeling when they can interact on real things. Every semester I always bring my students who learn Science and Buddhism subjects to study outside school such as temple, market, and gardens. These places are very near school and we are easy to walk there. I prepare various styles of teaching because I know that students' interests are different and they have different way to learn.
>
> (Malai's Interview 4# August, 2009).

In Malai instructional practice, even though she realized that teaching and learning science related to contexts of community, school, and students were crucial to teaching success, she did not use any sources in community around the school in the lessons that I observed. Students learned science only in classroom and all students did same activity, without responding to students' from different backgrounds. During our interview Malai commented that "the classroom environment should be silent and students should pay more attention to do experiments and to listen what teacher would like them to do." She preferred a quiet class during her teaching. Malai explained when students were quiet, it was easier to manage and control them.

Many aspects of Malai's understanding on contextual knowledge seemed to be she understood how to integrate contexts of district, community, school, and students into her lessons. Many times Malai implied that science teaching can be meaningful in coping with the demands of diverse learning populations if teachers make an effort to become knowledgeable about their own teaching context. But during my classroom observations these ideals were not in evidence.

Malai's Understanding and Practice of PCK After Participating in PCK-based CTM

In this section, the results are discussed in terms of Malai's PCK development through the activities in CTM. She had participated in the CTM from July 2009 until March 2010. The CTM was a long-term professional development. There were four stages of CTM (CTM I- CTM IV). For the second semester, Malai taught in unit of plant and animal. She used topic of plants to develop her lesson plans. These topics were Plant's Structure and Function, Plant transport system, Plant Life Cycle, and Photosynthesis. She started to prepare her lesson plan with other CTM members from November, 2009 after she participated in CTM II. Malai implemented the lessons by following the 5 Es inquiry process (DCIC and IPST, 2002). This process is the major teaching strategy for teaching and learning science in Thailand. The 5Es inquiry process consists of five steps: engagement, exploration, explanation, elaboration, and evaluation. Malai's subsequence understanding of PCK was interpreted by various sources of data. Classroom observations, interviews (Individual interviews and card sorting), reflective journals, inquiry-based lesson plans, and central meetings. The development of knowledge bases is presented by considering aspects of PCK; understanding and practice of subject matter, understanding and practice of pedagogical knowledge, and understanding and practice of knowledge of context.

1. Malai's Understanding and Practice about Knowledge of Subject Matter

Before attending the CTM III, Malai was provided a chance to express what science unit or topics that she was not confident in teaching. In the second central meeting, when researcher asked her to write these topics on a blackboard, she chose unit of plant and animal behavior for using in CTM. What had changed Malai's understanding and practice about knowledge of subject matter? This question took almost one year to answer. That time Malai was in CTM and she showed to CTM team that she was very active. Finally, the CTM team could see her progress in her instructional practice.

Sharing and Discussing as Tools for Improving Science Content

At the second central meeting, Malai told CTM members about her struggle in teaching of concepts of plant and animal. As she mentioned,

> …I remember that last year I had to teach this unit and I then just assigned students to search information and presented during my teaching practice. I still do not know what characteristics of living thing and non-living thing. When my students present about categorized plant into living things, I do not know what characteristics of living things. In photosynthesis concepts, every investigation that my students and I conduct experiments are following the teaching manual book.
>
> (Malai's Second Central Meeting # October, 2009)

These sentences were noted at the second meeting and also were in her reflective journal. In developing of lesson plans, Malai listed concepts of plant that students should gain from her class. She brought these concepts to discuss with CTM members. The first lesson that she co-taught with the researcher was the Plant's structures and functions; she went to the library to study by herself and then she wrote into her journal the parts of science content that she was confused about. Malai would first; consult with her co-teachers on these parts of science content; she then would bring it into CTM central meeting to share the knowledge with other members. In Malai's lesson plans, it showed that Malai's concepts of plants were correct.

Consistent to Malai's instructional practice, she taught students naturally. Students were asked to connect between concepts during Malai's conversation to her students in class.

Students: For my group, we observe plant roots. There are many types of plant roots that we recorded and drew pictures of plants. We started to look at the bottom of plants and that part is called roots**.** These structures are designed to pull water and minerals from whatever material the plant sits on. For water plants, the roots may be in the water. Most of trees, the roots go deep into the soil.

Malai: Near my house, there is a tall tree. It should have roots to take water and food from soil as your friend's report. How can the top of tree can eat food and drink water?

Students: I think that the tree should have big tube inside.

Malai: Do you agree to your friend's answer? and why?

Students: I agree with him that tree should have transportation system for food and water for every parts of tree.

Malai: Lets see the group observing plant stem and plant leaves. What did they find from their studies? After that we come back to discuss how the tree can grow and increase high every year.

(Malai's Classroom Observation #5 December, 2009)

With regarding Malai's practice, she asked many questions to her class of students. These questions encouraged students to think about conceptual linking. Data from classroom observations, reflecting journals, and inquiry-based lesson plans reflected that Malai understood concepts of plants very well. As Malai stated "Today when I taught, I felt very relaxed and comfortable. Every step was smooth. Because when I was teaching in my class, it reminded me as I was discussing in the CTM meeting. So, I just conducted my class like I was talking with my CTM team. (Malai's Written Reflection #13: December, 2009).

Co-Teaching Model Help Me to Be More Confident in Science Content Knowledge

After Malai participated in CTM as one co-teacher, her confidence levels in explanation of science content were different from the past. As data from Malai's card sorting interview, she selected a card that had a teacher who taught concepts of photosynthesis. The teacher mentioned that plants produce food in day time and breathe in night time. Malai did not agree with that content. She explained that plants were always in the processes of food production and air-exchange just that the rates of photosynthesis and respiration were different. (Malai's Card Sorting Interview#4 February, 2010).

With regard to Malai's Practice, she and her co-teacher (Sirod) taught about plant photosynthesis together. Malai asked students to compare rose trees, one was small in size and another was bigger, she asked her students this question "why do these roses have different sizes?" Sirod also added that the rose trees were planted at the same time. They continued the class like they were in active meeting and their students as listeners, questioners, and speakers. At the end of this class, Malai was interviewed by the researcher and she said that not only the science content that she had learned from CTM and her co-teacher, she also learned skills in science process.

2. Malai's Understanding and Practice about Pedagogical Knowledge

The CTM designed by the researcher and this CTM was based on teachers' data collected before they participated in CTM. The data involved developing understanding and practice of PCK. CTM was not short-term PD. A total of 32 weeks that three teachers were involved in PCK based CTM. Malai had to spend time together in sharing, reflecting, discussing, planning, teaching, and evaluating. As the following paragraphs explain what Malai's progress on her understanding and practice about pedagogical knowledge during and after she engaged to CTM. There were five aspects of knowledge presenting Malai's changes in pedagogical knowledge.

2.1 Understanding and Practice about Knowledge of Goals and Purposes for Teaching Science

Before Malai involved CTM, she had some traditional practices that emerged in Malai's classroom observations. She taught students by knowledge transmission that a teacher corrected students' alternative conceptions by telling and explanation. Consistent to Malai's initial understanding and practice about articulating goals and purposes for teaching science were focused on content knowledge as the central goals.

In CTM II: preparation and CTM III: Co-planning, Malai's changed her understanding of goals for teaching science gradually from the beginning of CTM until last day of program. Her changing of goals and purposes for teaching science were categorized into two aspects as follows:

Articulating Goals and Purposes for Teaching Science in Aspects of Science Content, Scientific Process, Scientific Attitude, and Attitude toward Science

Before attending the CTM, learning outcomes of Malai's lesson plans were focused only on students' learning in science content. Malai's initial practice always used didactic way. Transmitting the facts of science was often the teaching strategy in Malai's class. Since week 14 of CTM, Malai adjusted her understanding and practice about articulating learning outcomes in Science subject covering three domains.

In CTM IV: co-teaching and evaluating stages (week 26), Malai taught students the topic of plant roots. Students worked together in groups. She showed them real plants (green shallots, corns, carrot, and mango) and she asked them why plant roots were the last bottom parts of a plant? Does every plant have same characteristics of plant root? Why? Students were assigned to design their investigation and the way for data recording. Students had 1 week to answer these questions. Malai facilitated students to define investigative questions. The students observed plants that they were interested in and recorded data to formulate conclusions. One week later, each group brought their own data and conclusion into the classroom. Malai opened time for their presentations. Students were encouraged to discuss the lesson. In Malai's practice, students were fostered to gain scientific knowledge as active learners, to use scientific skills in investigating, and to apply scientific knowledge to solve local problems.

Teaching Students Nature of Science as Teaching Goals

As the CTM progressed, Malai's understanding and practices about setting goals and purposes for teaching science started to integrate nature of science as knowledge that students should learn, not only science content. Malai explained the nature of science shifted to be more constructivists, specifically, about the nature of scientific knowledge. In week 13 of the CTM, Malai had a chance to present her own ideas and read articles about the nature of science. During the CTM, Malai was provided with many opportunities to express her initial understandings and compare these understandings to constructivist understandings of the teaching and learning science. For example, in 15th week, she was asked to analyze and discuss goals of teaching and learning science proposed in the Basic Education Curriculum, and the Science Curriculum Framework. At that time, Malai realized that nature of science was important in aspects of teaching goals and leaning outcome.

According to her responses in the subsequence understanding and practices in real classroom, it was found that Malai's understanding and practices about scientific methods were more on constructivist in nature. She noted that there were many methods for obtaining scientific knowledge. She understood that scientific methods did not need to be series of making observation, formulating hypothesis, doing experiment, and concluding about results.

Additionally, Malai's understanding about teaching and learning science by learner- centered on constructivist understandings were unchanged, but broadened in terms of pedagogical knowledge. Contradictory, Malai's teaching was changed gradually especially when she co-taught with Napaporn (Grade 5 teacher). As Malai stated "I always thought that scientific knowledge cannot change forever because scientists spend long time to formulate theory and law. After I co-planned, taught, and evaluated with Napaporn, she showed me many documents that were useful for teaching science and I understood nature of science clearly because of her. (Malai's Interview#9: January, 2010). The data from lesson plans and classroom observations during four stages showed that Malai had more understanding to connect what she already knew from her experience to what she learned from CTM. Her instructional practices were aligned on her understanding. Malai's articulating of learning outcomes was covering the three aspects, scientific knowledge, scientific process skills, and scientific attitudes.

2.2 Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science

Classroom Lesson Introduction: Teacher Uses Students' Daily Lives to Motivate Students' Curiosities. Students' Prior Knowledge Is Probed and Used to Formulate Scientifically Oriented Questions

During the first central meeting, Malai compared teaching strategies of the CTM. Initially, she commented that her teaching was teacher-centered because she gave many assignments to the students. At the beginning, she thought that her classroom was student-centered. Malai became frustrated in her thinking about teaching strategies. Until CTM II: preparation stage, she was clear in her ideas. Through the preparation and co-planning stages in Weeks 13 to 20, Malai had learned about constructivist-based teaching strategies especially, inquiry approach. Generally, she felt that after participating in the CTM activities she better understood pedagogical sequences that might be used in constructivist-based teaching strategies. She had learned how to introduce and conclude a lesson, and how to connect learning activities in science lessons. As she discussed with other CTM members in the forth central meeting, Researcher: Good morning, I appreciate very much that you enjoy co-teaching. I read your co- teaching reflective journals and I think CTM should give back to you something. So, what did you learn from participating in CTM?

Malai: It is long-term professional development that is first time for me. It is very helpful for me. First, I know that I increased my scientific knowledge. I see the difference in my confidence when I was teaching in classroom before and after participating in CTM.

Napaporn: I can saw her development of scientific knowledge when I co-taught with her in concepts of plant structures and functions. She conducted her classroom smoothly. We were teaching in the classroom like a team. She helped me to start the lesson and she then asked students questions to create interest in my experiments.

Malai: I remember that class. It is fun class. Students paid attention to us and we discussed with students like we did with our microteaching in CTM.

Researcher: What else did you (Malai) get from the CTM?

Malai: My questioning skills developed. In developing lesson plans, I use questioning method to probe students' prior knowledge and introduce them to the lessons.

Researcher: How did you get the main question for your class?

Malai: The question developed from students' answers and' questions.

Sirod: When I taught with her (Malai), we spent 1 hour discussing and planning our co-teaching for next class. We prepared the questions that related to our science topics. In our instructional class, we tried to link students' answers and students' questions to main question.

Malai: For example, I asked students "What are differences of two rose trees? And students' answers were color of flower, size, weigh, number of leaves. I continued to ask students "why

> these roses are different size?" when students explained that the taller rose got more food and nutrients than shorter one. I adjusted students' questions into "What is the process that plants get food for developing and growing?"
>
> (Malai's central meeting#4: February, 2010)

Malai's development of pedagogical knowledge was presented in her classroom, she focused more on student thinking and their interests were important criteria of student- centered teaching. She thought that the lesson introduction should aim to elicit students' prior knowledge, and guide teachers in the next step of teaching. Teachers should ask questions that students were able to answer. To do this could attract students' interest. The data from interview and reflective journal showed that not only asking students questions, some classes Malai also introduced her class by showing real specimens, telling stories, and providing interesting news to students. With regard to Malai's instructional practices, she started her classes with scientifically oriented questions and the questions were based on students' interest, curiosity, and prior knowledge.

Investigation: Hands-on and Mind-on Are Integrated into Teaching Activities

To increase students' success in learning science, Malai's inquiry lesson plans were based on the 5Es and in the stage of exploration, students' investigation for answering authentic questions that were generated from student experiences was the central strategy. For example, in the lesson about structures and functions of plants, all the groups were provided opportunity to have Hand-on experience by surveying and collecting data from the schools garden. Malai's teaching was different from the first semester. Before students always conducted experiments following teacher's procedures. Therefore, her teaching was active directing until week 15 of preparation stage, Malai's constructivist view was consistently presented in her reflective journals during CTM. As Malai noted "Constructivist teachers should often ask questions to engage students' thinking or encourage students to ask questions in the classroom. The teachers should provide chance for students to plan and mange their own learning because they will know the meaning of what and how they learned" (Malai's Interview# 5: October, 2009).

Moreover, Malai's lesson plans were focused on Hand-on and Mind-on activities. Students conducted their own investigations. These lessons were about structures of plants. They got opportunities to design and manage their data in their own way. Every group presented their own data of plants that they went to survey. Students, co-teacher, and Malai then discussed the data and made conclusion that related to scientific concepts. At the end of lesson, Malai assigned students to create mind mapping that concluded what they learned? Students were asked to present their ideas on how they can use these concepts for developing local community? In Malai's worksheets, there were five open questions and they were about linking science knowledge into development of local community and how to maintain environment in society. With regard to Malai's instructional practices, after students, Napaporn (co-teacher), and Malai finished their discussion and got the central question that they would like to find an answer. Students were given time to formulate their hypothesis by group working. Additionally, they designed their investigation and data recording by group work. Malai better understood and practiced attributes of student-centered learning. Hands-on and Mind-on activities were significant criteria of student-centered teaching for her. For example in Week 16, As Malai mentioned,

> … I think, in student-centered earning, students should have opportunities to touch real things using their sensory organs to learn science. After that students should think and realize on how scientific knowledge relating to environment, and technology. The students should do experiment, analyze data, and make creative imagination.
>
> (Malai's Reflective journal# 11: December, 2009)

Related to data from central meeting, Malai discussed with CTM members and she shared her ideas of teaching and learning science through inquiry.

Students should be led to make their own investigations, and to draw upon their own inferences. They should be told as little as possible. Articulating hypothesis, planning, investigating, recording, discussing, and formulating conclusions were as major scientific process skills that Malai would like her students to get from her teaching. Malai's instructional practices were aligned to her understanding of Hand-on activity. As evidence below;

Malai:	From your answers and questions finally we get the central question for our class. Today, we would like to find the answers of what are common structures of plant?
Napaporn:	Today we will be act as botanical scientists. Each group has 30 minutes to survey and observe plants around the school. Before every scientists work, we need to discuss and plan what your group will record? And where your group will survey?
Malai:	Please read instruction and answer the questions first individually. After that share your answers to your group members and find the group answers. For part 2 on page 1, please discuss in your group and formulate hypothesis of this investigation.
Students:	Should I make table and record data from observation?
Malai:	Yes, you should but we will not require that you have to record by data table. Every group can design how to record data and please assign roles for every member in group.
Napaporn:	When you finish investigation, I will provide you flip chart paper for analyzing and concluding your data. Every group will get 10 minutes to present your group's hypothesis, what kind of data you get, and conclusion.

(Malai's Classroom Observation#11: January, 2010)

With regard to Malai's teaching practice before and after the professional development experience, the finding revealed that she could integrate what knowledge she learned from CTM team to her practice. Malai's initial understanding of teaching and learning through inquiry was not completely wrong. She was just confused and was not confident to implement her lesson. When Malai attended CTM, sharing, reflecting, and discussing with others helped her to adjust her understanding and practice of pedagogical knowledge related to reformed education and based on Constructivism. In Malai's instructional class, students were provided time to think about what is hypothesis? How to record the data? And what conclusions related to data? Malai gave students opportunities to learn science through Hand-on activities or investigations. Additionally, students were encouraged to link their experiences with the conclusions by creating mind mapping. Mind-on activity also was referred in this time as well. However, the investigations were still directed from teachers, not completely created by students. After professional experience, Malai's class focused on promoting students to involve in the design of experiments and creation of data collecting ways. Her students also got opportunities to start investigating their own interesting things.

Conclusion/ Explanation: Active Students Are Provided to Analyze Data and Formulate a Conclusion

Malai's prior understanding was students should analyze and formulate conclusion independently. However, in her real teaching practice, Malai let her students' present data and then she made conclusion for the students. Time constrains and teacher's workloads were major factors that obstructed her teaching. She could not have enough time to prepare her lessons. After Malai engaged in CTM for two semesters, she managed her time for attending CTM central meetings very well. Most meetings were set on weekday evenings. Malai mentioned that CTM helped her to save time for preparing lessons because CTM members worked as an active team so they always shared and did work together. Malai's lesson plans showed that she still understood that inquiry teachers should encourage students to be responsible for interpreting data and formulating conclusions. After professional experience, Malai added her comments on students, the teacher, or both parties should analyze data gathered from an investigation. Students formulated a conclusion/ explanation from evidence and their prior knowledge to address the scientifically oriented question. In addition, students, the teacher, or both parties should connect the conclusion/explanation to scientific knowledge.

Regarding to Malai's teaching class, she concluded a lesson and organized student scientific conceptions. Students participated in discussion and helped her draw conclusions about what they have learned. Malai blended her teaching from teacher to student-centered style. She improved her teaching strategy gradually. As Malai mentioned "Most of my classes, I always made conclusions for my students, this time I could see how much my students were surprised when I let them formulated their own conclusion based on their data. My class was fun because students had different conclusions linked to their experiences and prior knowledge. I used discussion strategy to get the main conclusion from students' conclusions. They were asked to give their own opinion on the conclusion too. (Malai's Reflective Journal# 14: January, 2010)

After experiencing the preparation stage of CTM, the data lesson plans, classroom observations, and individual interview showed that Malai's teaching could help students to formulate conclusions and Malai's instructional classes focused to connect the conclusion to students' prior knowledge. Finally, students were engaged to link the conclusion to scientific concepts as well, as the following evidence was illustrated in below.

Researcher: In your class, after students finished their investigations. Who analyzed data and made conclusion?

Malai: Students, my co-teacher, and I helped to formulated conclusion. Students were provided time to make their own conclusions in the first group. The students' then shared and discussed in class. My co-teacher wrote these conclusions on the blackboard and I then used aspects that were similar and clustered that into the central conclusion.

Researcher: How do you help students analyze data and make conclusions?

Malai: I asked students to write their own data on flip board paper and they discussed in their own group to formulate a groups' conclusion first. After that they presented their own conclusions to the other groups. We discussed the conclusions together. For our discussion, I always asked students to think step by step. Students were encouraged to see what differences were among their conclusions and why?

(Malai's Individual Interview# 8: January, 2010)

"… To promote students' understanding of science, teachers should know what the students bring into the classroom" was mentioned by Malai at the forth central meeting. She told CTM about how she explored students' prior knowledge. The first lesson, she asked students to answer questions before starting a lesson. For the second and third lessons, students wrote their experience and prior knowledge on Post-it notes. Last lesson, students created mind mapping using vocabularies that Malai provided to them. After every lesson, students and Malai discussed the results of the investigations. Malai asked the students the main investigating questions (scientifically oriented questions) again. She pointed out to the students to compare the findings with their previous answers that they wrote in their worksheets, Post-it notes, or mind mapping. As Malai mentioned "I tried to ask students to compare the results with their previous understanding. When they could identify what they had missed from the result, they changed their conceptions. I evaluated their conceptions change from their mapping" (Malai's Reflective Journal# 14: January, 2010).

To increase students' learning in science, mind and concepts mapping were integrated to Malai's teaching practice. Malai taught students about mind and concept mapping by giving examples of mapping in worksheets from the first lesson.

Communication: More Talking among Co-teachers and Students with Classroom Discussion, Not Just Presentation

Prior, Malai's understanding was science teachers should provide opportunity for students to share and discuss data. Her understanding was contradictory to Malai's teaching practice. In her initial classroom, she only assigned one or two group to present their data.

After Malai had professional experience, she created lesson plans focused on students' presenting, discussing, and evaluating. Malai still maintained her understanding of students' communication from prior study. Malai's response during interviews in the CTM II: preparation stage.

Researcher: What do you understand about students' communication?

Malai: In my opinion, I think students should have a chance to present their ideas and investigating data. They then have a discussion about that data.

Researcher: Did you provide time for students to communicate in your class?

Malai: Yes, I did but it was not every group to present their data. I did not have enough time for them.

Researcher: What did other groups that did not present their data do during their friends' presentations?

Malai: They had to listen and write the data and conclusions provided from the presenting group.

Researcher: What was your role at that time?

Malai: I was waiting to make conclusions from the students' data.

Researcher: After you attended CTM, we had a chance to discuss this topic. What you would like to adjust in your teaching for the next semester?

Malai: I still would like my students to have the opportunity to show what they conclude from investigations or experiments.

Students should reflect on other groups' data and conclusion. I would change my strategy from students' presentation to students' discussion. Every group would have chance to write their data on the chalkboard. I then would ask students to find similar and different things from these conclusions.

Researcher: So, now do you focus on students' discussions?

Malai: Yes, I do. Now I understand that there are many ways to promote students' communications. My initial understanding and practice, I understood that providing time for students to present their data was communication.

(Malai's Individual Interview# 5: November, 2009)

In Malai's first lesson, she co-taught with Napaporn on the topic of structures and functions of plants. Malai illustrated that she added more activities for students to present their data and conclusion. From Malai's interview (Previous example) was consistent to Malai's teaching practice. She provided 5 minutes for each group to present their data and conclusions. Malai used questioning method to encourage other students to express their ideas on students' presentations as evidence below.

Students: My group went to small garden which was located in front of the school. We found five types of plants. We recorded data by drawing pictures of each plant. From the data, we find that our plants have common structures even through there are different in size. The common structures are root, stem, and leaves.

Malai: Do others group have different results from this group?

Students: My group went to a botanical garden located at the back of school. We recorded data by pictures and we put descriptions under each picture. Our findings were quite different. We have two groups of plants. One group has root, stem, leaves, flowers, and seeds and the second group has only root, stem, and leaves.

Malai: How about other groups? Do you have anything different from the first two groups?

Students: My group went to an herb garden and we recorded data by describing. We observed sweet basils, chili trees, kaffir lime leave tree, and ka-proa basils. They have common structures that are roots, stem, leaves, flowers, and seeds. We were not sure about the black color seeds in the flowers of sweet basil plants were real seeds.

Malai: So, the common structures of plants in your group were root, stem, leaves, flowers, and seeds, right?

Students: Yes, they were.

(After seven groups presented their data and conclusions. Malai's co-teacher wrote the students' data and conclusions on the board)

Malai: Everybody please look at data and conclusions. What similar data do we have from the seven groups?

Students: Root, stem, and leaves

Malai: What different data do we have?

Students: Some plants have flowers and seeds.

Malai: Are they different plants from the data?

Students: Yes, they are.

Co-teacher: Do the plants have different size?

Students: Yes, they do.

Co-teacher: What plants did your group use to collect data?

Students: My group used mango tree, sun flowers, coconut tree, and lotus. They are different size.

Malai: What is our appropriate conclusion that can answer our question? (What are structures of plants?)

Students: Different plants have different structures.

Malai: What else?

Students: At least every plant should have root, stem, and leaves.

Malai: How about flower and seed? Are they important for plants?

Co-teacher: How do we plant sun flowers? Which part do we use to grow it?

Students: Flowers can change to fruits and they are our foods.

Students: I used to grow sun flowers with my mom and we used seeds.

(Malai underlined the data on the board and she showed students what structures of plant that they used in discussion.)

Malai: From data, conclusions, and our discussion, it shows that different plants have different sizes and structures. The important structures of plants are root, stem, leaves, flowers, and seeds.

(Malai's Classroom Observation# 5: November, 2009)

The second co-teaching of Malai, she showed that her understanding of providing students opportunity to share, reflect of teaching to student-centered way was gradually developing. Students communicated and justified their conclusion/explanation with other students. As Malai's reflective journal from this class, she mentioned that she felt very confident with content and teaching sequences. I knew that sometimes I forgot and passed over some questions. My co-teacher helped me by re-introducing them later in the lesson. We worked together very well.

In Malai's microteaching activity of the plant concepts, her teaching was more in line with constructivist understandings of learning. The learning activities focused on student conceptions and learning. For example, prior to teaching the plant concept, she explored student's prior knowledge about the living things, non-living things, and plant cell by distributing worksheets to students. After the students completed the worksheet, Malai and her students discussed the questions in the worksheet together. In summary, Malai developed her knowledge of teaching strategies. She added to her understanding of student-centered learning by providing students the freedom to learning what they wanted, more thought about student prior knowledge, and about hands-on and Mind-on activities as key aspects of student-centered teaching. The sharing, reflecting, discussing and evaluating on teaching were significant activities contributing to Malai's knowledge of teaching strategies.

Group Work: Sharing, Working, and Discussing as Responsible Roles for Group Members

After experiencing the CTM II: preparation, Malai began to understand the significance of students' learning through sharing, working, and discussing with other students. Consequently, she consulted this concern to other CTM members. Napaporn (5^{th} grade teacher) introduced social interaction and the best way that students could start to learn how to interact with others was engaging students to work as a group. The following evidence is discussion among CTM members during the second central meeting.

Malai: How can I set my class as our meeting environment? I would like my students sharing, working, and discussing their ideas in my classroom.

Napaporn: I think working as group is the best way for students to learn how to interact with each other. I usually teach students in groups because they can help each other. Every member in each group has to have his/her role and responsibility.

Sirod: I also used group work-as well but I did not focus on member's role.

Researcher: That is a good point. What do you think about social interaction on student's learning?

Napaporn: I think when students learn together, they have interaction processes. From working together students are provided task-oriented learning to relationship-oriented learning.

Malai: I have problems when I taught students and they do not help each others to do investigations and experiments. How should I prepare my students?

Researcher: Does anyone have any ideas?

Sirod: I always use member checking to enhance students' working together.

Researcher: How is it working in your class?

Sirod: It is very successful.

Researcher: How many students per group?

Malai: There are about 7-8 persons. I know that I should cluster only 5-6 persons per group but I do not have time to prepare lots of teaching materials for many groups at same time.

Napaporn: I think maybe you have to teach science using learning stations that students will learn different things at different stations at the same time. Teachers do not need to prepare lots of the same teaching material or scientific equipment.

Malai: Good idea, thank you so much. I think if I can organize students' learning through group work, they were conceptualized to lean about social interaction. They should be good citizens for the community, society, and the nation. In addition, in mixed ability and gender groups, students would get intellectual influence. They can share any knowledge that they have at different levels.

(Malai's Central Meeting# 2: October, 2009)

Malai's conversation during the second central meeting also showed that she recognized that students' interaction with the activity was decreased when there were too many students in a group. She realized that promoting students to have social behavior could happen in classroom starting from teaching the students how they work as a group. Teachers should engage students to participate in task-oriented learning and help the students move to relationship-oriented learning.

With regard to Malai's practices of four lessons, the result presented that students in Malai class were clustered into groups and there were 5-6 persons per group. Students who were in each group were mixed genders and abilities. Students were grouped by picking a ping-pong ball. In The first lesson, Malai assigned students to work as a group for investigating structures of plants in school. The second to forth lesson, she used learning stations. Therefore, she did not have any problems with not enough scientific equipment.

From Malai's teaching practices in CTM IV: co-planning and evaluating stage, they were aligned with her understanding. Students assigned to organize their own roles in the group. They had to put their name, surname, and role. Malai checked students' progress during experiments by check list. Additionally, the students in each group had to evaluate and assess by member checking.

2.3 Understanding and Practice about Knowledge of Science Curriculum

Science Curriculum and School-based Curriculum Are Used as Framework for Science Content, Teaching and Learning Goals

Initially, Malai conceived that the science curriculum standard was a framework of science content. She used only science curriculum standard to know what topic of science that she had to teach for 4th graders. However, after discussing and participating with the CTM team, Malai focused on the importance of the National Education Act and its relation to the Basic Education Curriculum and the Science Curriculum Framework. She provided an extensive reflection on her learning in her written reflective.

> …I've learned what the National Education Act is, and the content in each chapter. I've learned that the development of the basic education curriculum is based on the Act. Participating in analysis of the national requirements revised my prior understanding about students' construction of knowledge. I have a better understanding of science curriculum; especially strand 1, 2, and 8. These strands relate to general science content. When I plan my lesson, I understand how to interpret curriculum and link to my lesson. Now, I use science curriculum not only for science content, I also realize about the goals

> for teaching and learning science described. So, I implement my understanding of the national framework to reflect on the classroom teaching. From CTM meeting, we discussed about how to bring the national requirement into classroom practice? I have learned many things from that sharing. I plan my lessons related to curriculum goals as well
>
> (Malai's Reflective Journal # 11: December, 2009)

In order to broaden her science curriculum knowledge, Malai was required to work with a co-teacher to conduct school-based curriculum in the CTM III-IV. She came to the CTM meeting and shared what she had learned from preparing lesson plans with CTM team. In her understanding, Malai felt that the discussion in CTM central meeting helped her to have better understanding of the curriculum. She had learned about school-based curriculum development and scientific literacy in curriculum. Additionally, in the classroom discussion she shared her understanding that school-based science curriculum was developed for science teaching. The school relied on the science curriculum framework in which students in elementary school level learned science using learning standards. At the elementary school level, goals of teaching and learning science also relied on the science curriculum framework and students learned science from the standards proposed in the framework. For Malai, the learning outcomes in strand 8 (the nature of science and technology) was new for students and teachers in the school. At the end of CTM III, Malai and her co-teacher had opportunities to compare and analyze science content in the Science Curriculum Framework and in school-based curriculum. From this discussion, Malai also mentioned that she developed an understanding of science curriculum particularly strand 1 and 2. She noticed that the science content for basic science in the school-based curriculum was similar to the content in strand 1 of the Science Curriculum Framework.

From Malai's lesson plans, she demonstrated considerable understanding of the science curriculum including the goals of teaching and learning science, learning standards, and school-based curriculum development. This understanding was influenced by her self-study, sharing, reflecting and discussing about science curriculum framework with CTM team. Malai also learned the development of school-based science curriculum which depended on the number of science teachers in a school. Contexts of school and local community should be integrated in school-based curriculum. Malai presented that she should encourage students apply science knowledge into their living styles in the local community.

2.4 Understanding and Practice about Knowledge of Assessment in Science

Scientific Concepts, Scientific Skills, Scientific Attitude, and Attitude toward Science Are Aspects for Evaluation and Assessment of Student's Learning

Malai gradually developed her knowledge of assessment through the CTM. As the CTM progressed, Malai gained better understanding of aspects of student learning because of what she experienced in the CTM II activities. She learned goals of teaching and learning science from the Science Curriculum Framework. Malai indicated that the goals and purposes of leaning science are: understanding scientific concepts, possessing process skills, creative thinking, and conceptual understanding, ability to solve problems, and have scientific minds. As she noted in her reflective journal "I developed my lesson plans with my co-teacher (Sirod) on the topic of photosynthesis. We discussed about goals and purposes for teaching science and we expected that our students should understand and explain the concepts of photosynthesis; use appropriate scientific skills in experiments; conducted investigation as scientists. (Malai's Reflective Journal# 12: December, 2009)

With regard to Malai's instructional practices, the results presented that Malai implemented the lessons following her plans. The first two lessons, she focused to assess students with traditional pencil-and paper tests at the beginning of lessons. These tests were developed before she participated in CTM. She added space under each question for students to write their reasons "why did they answer that choice?" During her class, students were to investigate the factors required by photosynthesis. She always asked students questions to explore what the students understood and facilitated them to interpret data. As Malai's instructional practice below,

Malai: From last week, every group design and observe your morning glory. So today let's see how are your morning glories are growing? Could group 1 tell me what data your group has after week 1?

Students: Our group designed to plant 5 morning glories per container. We put water in the first container every morning and evening but did not do that for the second container. We measure the height of morning glories and size of stem. After one week, the first container, the morning glories are very tall and have green colored leaves. For the second container we do not give any water for them. These morning glories change to have yellow leaves and sear. At day 5, only 2 morning glories are left in the second container.

Malai: What different factor did this group provide for the two of containers of morning glory?

Students: Water

Malai: Do you think water is important for plants? Why?

Students: Yes, it is because water can help morning glories grow.

Malai: How does morning glory grow?

Students: Morning glory increases in height.

Malai: Is it same like humans?

Students: Yes, it is.

Malai: What do humans do for growing?

Students: Eating foods and drinking milk.

Malai: So, plants also eat and drink. What food do plants eat? Could group 2 tell me what happen with your morning glory after one week?

(Group 2 gave nutrient to the first container of morning glory but not for the second one)

(Malai's Classroom observation# 14: February, 2010)

During the instruction practice of testing plant's leaf, Malai and her co-teacher walked around the student groups and observed the students' performance showing their skills in scientific equipment. Two teachers introduced some students on how to use beakers and graduated cylinders.

Additionally, Malai's progression in an understanding of student learning in aspect of social interaction was evident in her professional experience through CTM's practice. For example, Malai included social aspects as learning outcomes as well as conceptual aspects. Therefore, she expected her students to work cooperatively and to use scientific concepts to maintain plant diversity in students' local communities.

Summative and Formative Assessments Are as the Major Methods to Understand Student's Learning in Her Classroom

Malai also developed her understanding of summative and formative assessment methods through sharing, reflecting, and discussing among CTM team. For summative assessment, Malai thought that there should not be multiple choice tests. Written tests and oral examinations might be alternative assessment methods for teachers, and she thought that these methods helped the teachers get into what students really understand. Regarding Malai's classroom observations, Malai and her co-teacher (Sirod) used written tests to assess student learning. Malai showed the picture of a leaf and she then gave the students five words (Carbon dioxide, light, water, chlorophyll, and starch) Students were assigned to use these five words explaining the process that happened on the picture. As Malai mentioned after her class "My co-teacher and I thought that this assessment method helped the teacher come to know about students' thinking and conceptions".

Moreover, in Malai's instructional practices, worksheets also were used to identify students' understanding after finishing her teaching.

Malai' reflection on the teaching with co- teacher during discussion of CTM central meeting indicated that she had learned and developed her understanding of formative assessment. She thought that formative assessment should be used to probe students' prior knowledge in the lesson introduction. Specifically, she stated that:

> …From CTM experience, the teacher used pictures to ask students at end of the class to conclude how much students understand the concepts. But there should be assessment methods before teaching, in order to know whether and how students had prior knowledge.
>
> (Malai's Central Meeting# 3: December, 2009)

As previous example of dialogue in her instructional practices showed Malai's development of knowledge of assessment, especially in formative assessment. Malai asked the students a lot of questions and tried to clarify and diagnose students' answers.

In summary, Malai developed her knowledge of assessment in both aspects in teaching; understanding dimension of student learning, and assessment methods. She appeared to be more focused on cooperative learning as one aspect of student learning. She thought asking questions of students, observing their behavior, and getting more interaction were important alternative assessment methods. Her knowledge of assessment was influenced by sharing, reflecting, and discussing on teaching and learning based on science educational reform during CTM progression.

2.5 Understanding and Practice about Knowledge of Learner and Learning

Students' Prior Knowledge and Difficulty Are Probed during Co-teaching

In Weeks 21 to 24, Malai also had a chance to share, reflect, and discuss on CTM members' teaching. She participated in microteaching activities in which the CTM members played the role as a school teacher, teaching the concepts of plants. After the microteaching, Malai shared her ideas about the instructor's teaching, especially about the importance of students' prior science conceptions. She used a lot of questions to ask students' prior knowledge. She shared her ideas about science concepts related to teaching the structures and functions of plant concepts:

> …I think before learning this topic [structures and functions of plant], students should learn the concepts of cells, tissues, organs, and system, and the concepts of characteristics of living and non-living things. After learning this topic, students should learn plant diversity, plant behavior, and ecology.
>
> (Malai's Central Meeting# 3: December, 2009)

This understanding of science conceptual framework related to her curriculum knowledge. Since Malai had a better understanding of the science curriculum especially in sequencing science concepts in elementary school teaching, she could apply that understanding to identify which prerequisite science concepts students should know before teaching specific science content.

Malai learned that students had their own prior knowledge before learning science and this knowledge was important for teaching. Malai noted this idea in her reflective journal. From the teaching experience, after her class, Malai discussed with the researcher about her implementation of lesson. She mentioned that "I thought lesson introduction was aimed at eliciting student prior knowledge that could guide teachers' teaching in the next steps". (Malai's Interview# 9: January, 2010)

Malai's Knowledge of student learning came from co-teaching observation. Throughout the CTM, Malai had opportunities to co-planning,-teaching and-evaluating with other co- teacher's teaching in real classroom situations. Every week after co-teaching, Malai came back with information to discuss with CTM members in central meeting. Her ideas about co-teaching were reflected in her better understanding of student learning. She had learned that science teaching should be flexible and meet student grade levels and their learning style. Specifically, Malai noted that;

> …Communication between teacher and students are very important. If students can feel that teacher understand them, the students will be comfortable to express their thinking and actions. The students will tell teacher what concepts they understand or what concepts they still are confused and need more suggestions by the teacher.
>
> (Malai's Reflective Journal#18: February, 2010)

The Learner as Unique Individual: Different Students Are at Different Levels of Abilities and Interest

From Malai's reflective journal after CTM I: exploration stage, she realized the importance of individual student differences in classroom teaching. Malai felt that it was not good to separate high ability students from low ability students, because the teacher might not take care of the low ability students. She thought that high ability students in each group were the only ones who did activities, while low ability students did not have a chance to participate in the activities. Consequence, Malai kept clustering students by mixed genders and abilities. Consistent to Malai' lesson plans created after she got professional experience, the results showed that Malai had started to do students' portfolios for science subject. She collected students' profiles, students' works, and students' examination results.

The students' profiles had information of each student (name, gender, birthday, and interesting hobby). Malai designed her lesson plans intergraded learning stations to the second lesson plan (plant vascular system). She prepared various activities for diverse learners. In the third and four lesson plans, she adjusted her teaching strategies using the students' parents as the second teacher at home. As Malai stated,

> …Teachers should use differentiated teaching to cater to diverse learning needs. I think all students are different in terms of their achievement, ability, learning and cognitive styles as well as attitudes, pace of learning, personality and motivation. Using differentiated instruction, teachers should cater to a wide variety of varied interests, students' backgrounds and world knowledge which results in more dynamic classroom interaction.
>
> (Malai's Interview# 9: January, 2010)

In Malai's teaching experience, she provided various activities for all students who did not learn in the same way. In addition, it was common for a class of students to be at a variety of levels. Malai used different teaching methods in order to reach all students effectively. During Malai's teaching class, inquiry-based teaching, cooperative learning, and problem solving were prominent strategies that she often intergraded into her lessons, as she mention "A variety of teaching strategies, a knowledge of student levels, and an implementation of which strategies are best for particular students can help me to know which teaching methods would be most effective for my class" (Malai's Reflective Journal# 15: January, 2010).

Students Are Active Investigators and Creative Thinkers

After Malai received the professional development experience, she conceived that students in science classroom should be active learners, Mind-on investigator, and creative thinker. She suggested to CTM team that the instructor and the learners should be equally involved in learning from each other. With regard to Malai's lesson plans, the results confirm that Malai provided students activities that the students work as an active group and they designed their experiments and investigations by themselves. Malai was the consultant and facilitator for them when they had problems or questions. Some activities students were encouraged to work with their parents such as students interviewed family members "how to be environmentally friendly?" Malai's teaching engaged students conduct Hand-on activities, design creatively, think critically and logically of the activities, and significantly know the main problems or questions that their groups would like to find the answers and understood the purposes that were addressed in the activities.

Teachers Play Multiple Roles as Major Factor for Successful Teaching

In week 13, Malai told CTM members story of her teaching. Her initial teaching style was like a lecturer and explainer because Malai understood when the students who paid attention to teachers; they would influence their understanding of science concepts. But after tests, Malai was curious why students might not pass a test when they could answer the teacher's questions in class. She noted that when observing students, it seemed that they understood the content very well, but they could not pass the test. Malai discussed this problem to other CTM members. The CTM team agreed that this problem happened because students might not understand what they learned. She felt that the students only understood the conclusions made about the concepts, but did not know the reasons behind the conclusions. In CTM III: co-planning stage, Malai expressed that she should act in various roles, starting from a preparer of teaching and learning materials, a prober of students' prior knowledge, a motivator of students' interests and curiosities, an advisor of students' investigations, and a facilitator of students' learning. With regard to Malai's teaching practices, the finding revealed that her practices were considerably aligned with her understanding. However, sometimes Malai used director and lecturer roles too when she and her co-teaching did not have enough time.

In summary, Malai's development of knowledge of student prior conceptions and learning was noticeable where she appeared to recognize the importance of a student's prior knowledge and individual differences in learning. She learned that the students had different science conceptions. Some students held correct conceptions but some did not. This development came from reflection on her and others' teaching, and discussion about student learning during CTM experiences.

3. Malai's Understanding and Practice about Knowledge of Context

School and Community Contexts Are Integrated into Her Teaching Activities

From Malai's lesson plan, the results showed that she created several activities in worksheets related to students' local communities according to suggestions that came from the CTM group. Especially in exercises, students were provided news to read, events, or articles that happened in students' local communities. Malai used these activities for engaging students' curiosities and promoting students' thinking. As Malai mentioned,

> …I really would like my students to apply scientific knowledge that they learn from my class to improve their lives, supporting local community and maintaining our local environment. My teaching goals were focus on students' recognitions of values of their communities and environments. They can maintain and develop environment, community and society effectively. Not only students are learning science for developing their communities, I also integrate school and community contexts as teaching materials for encouraging students' success in science learning. Some activities students have chances to interact with people in community to exchange their experiences and knowledge.
>
> (Malai's Card Sorting# 4: January, 2010)

With regard to Malai's instructional practice, she engaged students by asking the questions that were related to their context e.g. "what happen when we cut big trees in front of our school for the new building?, how long does it take for durians' flowers to change into fruits?, why do we see a lot of bees around durian trees when the trees have flowers? Malai said that when she asked students these questions, students were very active answerers. They had experiences from their homes and parents' jobs. After students learned topic of plants, they had opportunity to interview their family members or local people in markets with the question "how to be environmentally friendly?" They then shared their information as a group. Malai discussed this activity with CTM team and she stated "learning science does not happen only in classroom. Students could understand and learn science more when they have chance to interact with others" (Malai's Central Meeting# 5: February, 2010).

Scientifically Environment in Classroom as Students' Motivators

After Malai had experience of professional development, she decorated her classroom with pictures of plant, structures of plants, plant cells. She said that the classroom atmosphere was an important encouraging factor on students' curiosities as evidence below,

> …My students were very excited to see many pictures on the wall and they started to ask me what these pictures were. So, I think this was good for a starting lesson. I also put the students' work on the board as well. They could learn from each other and they should be proud of themselves when they saw an individual or groups work shown on the board.
>
> (Malai's Central Meeting# 4: January, 2010)

Malai presents her understanding in CTM meeting that she would like to make the room attractive and functional for engaging student learning in Science subject. Teachers should consider grade/age level appropriateness, the type of classroom activities the teachers would be implementing, and their particular style. For example, considering the various areas of the classroom and design those areas for use in a variety of activities. The physical aspects of students' rooms include room arrangement, seating, bulletin boards and black/white board displays and physical climate. As she wrote below,

> …While I consider how to arrange your classroom, several things are important to remember. The seating arrangement should be designed in a systematic way so that the organization of the seats helps the students to feel more organized. Sometimes, this sense of organization is helped if students have assigned seats. Make sure the room has only the amount of furniture that is functional and does not contain useless or non-essential furnishings. The entrance to your room and the hallway outside should not cause distractions to students during lessons. Additionally, seats should be arranged in such a way as to reduce traffic distractions. Allow plenty of space for foot traffic, especially around areas where supplies are stored. After organizing students 'seats, I think about how to make room interesting for my first lesson plan so I talk to my co-teacher(Napaporn) that I would like to decorate our classroom as a science room, putting interesting pictures of plants, plant's structure, plant's cell, and examples of real plants. She agrees with me that we should make students feel comfortable and interested in our class. In addition, we also provide one board for students' work. (Malai's Reflective Journal# 14: January, 2010).

At the first time for co-teaching between Malai and Napaporn, they help each other to decorate the classroom three days before starting their classroom. Every evening they came to the room and planed how they would organize and decorated the room. The first day of co-teaching, the students walked into the class and were very excited to see their new class. While Malai co-taught with Napaporn, students were asked to interact by reading posters on the wall when they finished discussion and conclusion of that class (Malai's Classroom Observation# 5: January, 2010). In Malai's teaching practices, she provided the students with good an atmosphere even though she did not have much time for preparation; the co-teacher helped her complete the classroom. As she said in interview,

> …If I have to decorate the classroom by myself, I am not sure that I can finish it. I do not have enough time to do it alone. But this time Napaporn helped me to plan, organize, and decorate the classroom. We shared our ideas on how to make the room interesting and have a good environment for students' learning science.
>
> (Malai's Interview# 12: January, 2010)

Malai's developments of her understanding and practice of PCK was gradually changing based on constructivist teaching and learning. Providing her opportunity to have a team for sharing, reflecting, and discussing was an effective professional development on Malai's improvement for her knowledge and interpretation the knowledge to her practice.

Summary of Malai's PCK Development throughout the PCK-based CTM

When coming to the PCK-based CTM, Malai expected to learn teaching skills, examples of teaching strategies to help students learn by themselves, apply their knowledge in their daily lives, and activities that could cover the content students needed to learn. She experienced science learning in elementary school that relied on a teacher-centered approach. Malai was a reflective practitioner, and very open during classroom discussions and in the reflection written in her journal entries. Her initial understanding and practices of PCK in aspects of subject matter knowledge, pedagogical knowledge, and knowledge of context were not based on constructivism. She had problems with her knowledge of science content because she did not graduate from the area of science education. Malai just moved from teaching Social subject to Science subject. She was not familiar to engage students learning science. When the researcher provided her the CTM professional development, she immediately accepted to be one of three research participants. Malai is a very creative teacher in worksheets' development. The worksheets were very interesting but activities and exercises still supported a teacher-centered approach. Malai's initial lessons focused on students' learning science content as the major teaching and learning goals. From the first interview and card sorting, the results showed that Malai also intended her students to have scientific skills, scientific attitude, and attitude toward science. But she did not directly mention about these aspects of goals and purpose for teaching and learning science. She relied on students' applications of scientific knowledge into their daily lives, family, and community. In addition, Malai also stated about the nature of science as learning goals and purposes (definition of science, tentativeness of scientific knowledge, characteristics of scientists, and interaction of science-technology-society) relied on contemporary, and constructivist understandings. Her understanding and practices about teaching and learning science centered on contemporary constructivist understandings in which her goals for learning science were to understand and explain natural phenomena, and bring scientific knowledge to apply and use in a positive way. In her teaching practice, she thought teaching and learning science through inquiry approach based on constructivism, should give students chances to learn by themselves, and touch real things.

Malai's initial PCK knowledge base was limited. She had not learned about the science curriculum, so her prior knowledge of curriculum was weak. Even though her understanding and practices about teaching and learning science were contemporary constructivist, her knowledge of student learning and teaching strategies was based on positivist understandings. In her first teaching activity about the food and nutrients, Malai rarely focused on prior knowledge and learning, and most learning activities were based on lectures. Initially, she was frustrated with the ideas of student-centered teaching. Her knowledge of assessment centered on conceptual knowledge and heavily emphasized non-specific assessment methods. She especially paid more attention on paper-pencil tests and worksheets for evaluating students' learning at the end of course following school's requirement.

As the CTM progressed, Malai's PCK knowledge base gradually broadened through learning activities in the CTM. Malai was provided with many opportunities to broaden her understanding and practices about the nature, teaching and learning science. She had a chance to express her initial understandings and compare these understandings to constructivist understandings of the teaching and learning science, proposed in the Basic Education Curriculum, and the Science Curriculum Framework.

Malai was one of members in CTM team therefore she did not work alone. Malai was provided interesting ideas from her CTM members through sharing, reflecting, and discussion during her co-planning, co-teaching, and co-evaluating. Through these activities, Malai's understanding and practice of PCK supporting teaching and learning science based on constructivism shifted to more constructivist understandings specifically, in the nature of scientific knowledge. Malai's understanding of science curriculum was influenced by analyzing and discussing the science curriculum framework, and from the reflection with the CTM team about school-based science curriculum. Unlike her co-teachers, Malai thought that reading the Basic Education Curriculum and the Science Curriculum Framework did not help her understand science curriculum. However, when she was asked to analyze content the Science Curriculum Framework, discuss, and reflect her ideas with the CTM members about school-based curriculum development, Malai came to understand more about goals of teaching and learning science, learning standards, the school-based curriculum, basic science and advanced science. Additionally, making observations of the co-teacher's practice and discussing about students' prior knowledge and learner's learning enhanced Malai's awareness of the importance of students' prior knowledge and individual differences in learning. She learned that the students held different science conceptions.

Sharing, reflecting, and discussing during co-planning, co-teaching, and co-evaluating of CTM were key activities in the CTM that enhanced Malai's PCK development. Through participating in the CTM, Malai's understanding about student-centered learning became clear. In her broadened ideas, students prior knowledge, and participating in hands-on activities were key aspects of student-centered teaching. Malai also had a chance to clarify her understanding of how to integrate knowledge bases for teaching particular content. As a reflective practitioner, her reflection on her own teaching helped her become aware of the importance of each knowledge base for teaching and its integration. In her second lesson plan about the plants vascular systems, learning goals and purposes, learning activities sequence, instruction media, and assessment methods, had more detail and were more interrelated. She appeared focused more on teaching science by inquiry approach and enhanced students to learn science by cooperative learning as one dimension of student learning, and used a variety of assessment methods such as asking questions of students, observing their behavior, and interaction with them. These student-student and student-teacher interactions appeared in her microteaching activity. When she brought her PCK into teaching practice, Malai's microteaching with her co-teacher showed her development in understanding and practice of PCK for constructivist teaching and learning gradually.

Malai was an opened mind teacher. She improved herself by accepting CTM members' comments and suggestions. For the four times of co-teaching, Malai showed CTM team that her classes were very developed with a friendly and comfortable environment, interesting teaching and learning activities, and various types of assessment methods.

The Case Study of Napaporn

Napaporn's Background Information

Napaporn was a 53 year old woman. She was an experienced science teacher with 11 years of teaching experience leading into the 2009 academic year. Napaporn and Malai were colleagues. They both taught at Wattanawan School, a public school which is funded by the government. She completed a Bachelor's degree of Physical education from government universities in the province of Bangkok.

In the 2009 academic year, Napaporn had 36 hours a week of teaching responsibility. She spent 12 hours per week teaching General Science in 5th grade. Napaporn taught Fundamental Vocation for 6 hours per week. For the remaining 18 hours were devoted to Physical subject, Science Club, Science Laboratory room, Scouts, Head of Science Department, and classroom counseling. Napaporn indicated that her non-teaching assignments had taken more time than her teaching responsibility. Napaporn had many duties that did not involve science teaching, these included, being homeroom teacher and head of several upcoming activities during the school year, such as Science Week, Sport Day, Science Camp, and Science Competition. During the past five years, Napaporn had attended several workshops provided by educational institutions and her school. These workshops focused on curriculum, lesson plan, instructional media, teaching methods, science content and learning and teaching assessment. She said that most of these workshops were set on weekdays therefore she needed to leave her classroom. Napaporn assigned homework for students and asked other teachers who were not science teachers to take care of the class for her. (e.g., Thai Language teachers or English teacher). She always mentioned that she did not graduated from science education but she learned science content from attending workshops providing by IPST and school district. In addition, Napaporn stated that she loves to teach science more than other subjects even though she did not have any science background. For school curriculum, her responsibility was the main person for creating school-based science curriculum including selecting manual and activity books for 5^{th} graders.

In the first interview by card sorting, Napaporn chose a card that represented her teaching styles in the Science subject. She taught science by having students do activity and laboratory that she prepared for her students. The students read from a textbook and completed her worksheet and they then conducted laboratory experiments. She gave the students instructions for experiments first, the students then conducted explorations following her instruction, following which, the students would write reports on their findings. She lectured students before and after the experiments. Napaporn indicated teaching science in her lessons included a variety of activities such as students conducting experiments, observing teacher’s demonstration, watching VDO about scientist histories, participating in presentation and discussion, and creating science projects. In classroom observations, Napaporn began her class by discussion of the previous lesson concept and activities and student assigned tasks. She concluded the previous concept by asking students to present their understanding of science content that they learned from the previous lesson. Napaporn then concluded the main content on blackboard and had the students write these conceptions into their notebooks.

When coming to the PCK-based CTM, Napaporn expected to learn: teaching skills, examples of teaching strategies integrating with science content, teaching strategies that made students learn by themselves and apply their knowledge into their daily lives, activities that can cover the content students need to learn, and assessment methods for students' learning in Science subject. In this case, Napaporn viewed the CTM as a new thing that would be knowledgeable and enjoyable to participate in. Throughout the CTM, she was open-minded regarding her involvement in classroom discussion and reflection in journal entries. She often expressed her feelings directly to the CTM team.

Students' Background

In this study, classroom observations were conducted with a class of 5th grade students. There were 40 students, comprised of 26 females and 14 males. Most of the students were from working-class families and lived residentially in the vicinity of school. Many of the students had an average to low achievement scores in science. The average grade was 2.5-3 from a scale of zero to four while the students were in the 4rd grade.

In the first interview, Napaporn expressed her understanding that her students lack basic scientific content and skills needed for Science subject in 5th grade. The students had less experience in science's experiment and equipment therefore she had problems when the students were assigned to conduct experiments. They could not use science equipments properly. She needed to show students how to do experiments step-by-step and then students followed her instruction. In addition, students also did not have skill in discussion therefore Napaporn had to be the leader for her class. She told students the conclusion of an experiment and she then asked students "is the conclusion right?" The students only answer with "yes it is". Napaporn had to tell them the right answers and assigned them to record these answers to their notebooks. Napaporn believed that to be successful in learning science the students needed basic knowledge about the concept of study and learning scientific process skills. She did not mention on scientific attitude and attitude toward science directly. Most of the students in the classroom had financial problems. Parents could not provide enough materials for learning in science. As the result, Napaporn had to purchase teaching and learning materials for the students from her own personal budget. She revealed that she could not prepare the materials for every student.

From classroom observations, Napaporn and her students had a good relationship in and outside the classroom. She was pleasant with students. Napaporn expressed that she viewed herself as a students' friend. The students could come and consulted her anytime. She always used informal talking with the students in her classroom to make a friendly atmosphere in her lessons. Napaporn thought because of this kind of relationship, the students could talk openly with her. She wanted to gain the students trust and respect. Napaporn mentioned that students would learn more in any subjects if they feel comfortable with the teacher of those subjects.

Classroom Context

In this study, the observations of Napaporn's instructional practices were conducted in science laboratory room. The science laboratory room had many science supplies. The eight lab tables were organized in the middle area of the room. Each table was surrounded by 5-6 chairs. There was one blackboard and one white board permanently connected to the wall in front of the room. A teacher's desk was situated nearby the blackboard. Windows were located along the right side of the room. There were no decorations on the wall of both sides of the room. There was a television in the room, but it was never used for teaching. Three bookshelves filled with textbooks, supplemental books, and some lab equipments were placed in the back of the room. One shelf filled with DNA models, plant and animal cell models, and microscopes. On the right side of the room near window, there were two cabinets filled with supplies, glass, measurements, and chemical substances. Between the two cabinets, there was one sink. At the right corner on the back of room, there was one big human body model. There were two boards filled with announcements, and students' works. During classroom observations, the researcher located herself to the back of the room close to the window. A layout of Ms. Napaporn's science classroom is displayed in Figure 4.2

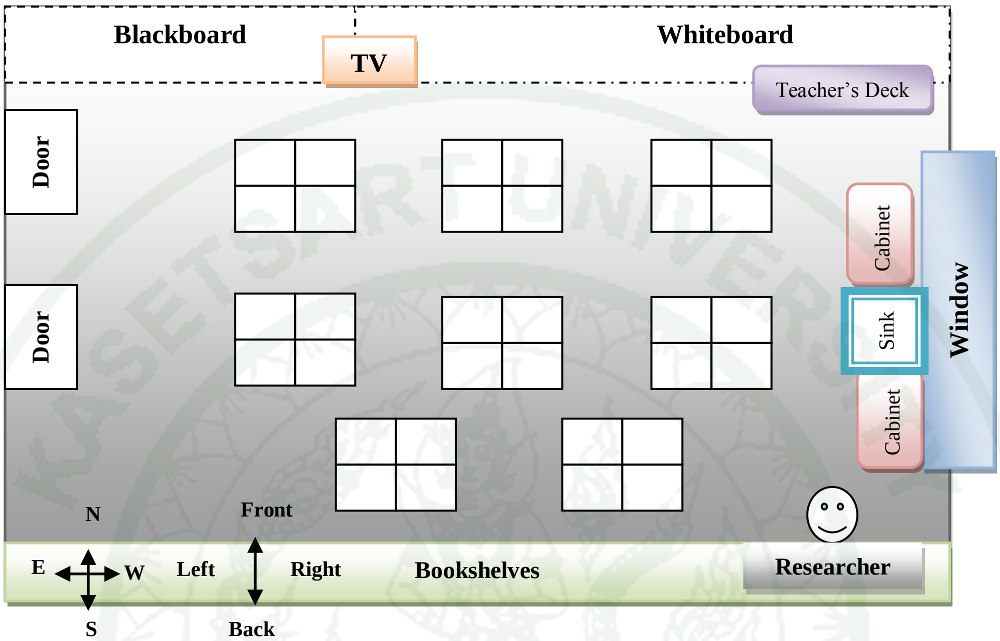

Figure 4.2 Layout of Napaporn's School Science Laboratory Room in 5th Grade

Napaporn's Understanding and Practice of PCK Before Participating in PCK-based CTM

In this section, the results are discussed in terms of Napaporn's PCK development through the activities in CTM from the exploration phase: CTM I- the preparation phase: CTM II. The development of knowledge bases is presented by considering aspects of PCK relevant to the CTM learning activities. Aspects of PCK presented below are: understanding and practice of subject matter knowledge; understanding and practice of pedagogical knowledge; and understanding and practice of knowledge of context. The period of time before the three case study teachers were provided professional development experience from the CTM. Napaporn participated in interviews, classroom observations, reflective journals, and card sorting. For her unit were about Light and Sound including 1) Light and Light Wave; 2) Colors and Reflection; 3) Lenses and Refraction; and 4) Sound and Sound Wave. After implementing each lesson, Napaporn then wrote a reflection on her lesson plans and teaching experiences to share and discuss with the CTM team in the first central meeting (Activity II) at Kasetsart University. Napaporn's prior understanding and practice of PCK was analyzed from multiple data sources, individual interviews, card sorting, classroom observations, teachers' written reflections, teacher's initial inquiry-based lesson plans, and the first central meeting. The data was analyzed and presented by case study individually. The prior understanding and practice of PCK is expressed into three main aspects of essential features of PCK.

1. Napaporn's Understanding and Practice about Knowledge of Subject Matter

Active Learner Helps Her to Be Confident in Science Content; However, She Did Not Teach Complete Science Concept

Napaporn did not a have science background. She taught science because she loved in science subjects. From the first interview, Napaporn said that she learned science content by herself. She studied from science textbooks. From Napaporn's lesson plans, the result showed that she did not described the complete concept of light and sound. She gave only the meaning of light and sound. Napaporn did mentioned that light is a form of energy that travel in waves in all directions from the source. However, she did not engage students understanding that light travels in a straight line. For her first lesson plan (Light and Light Wave), She explained that light only came from sources such as a candle, a light bulb, a fire. Napaporn did mention about light traveled through mediums such as air, water, and glass. However, she did not cover the concept that light can travel trough empty space where there is no air as in outer space between the sun, moon, and earth as well as the concept that light rays can bend.

With regard to Napaporn's teaching practice, students were provided to conduct experiments about transmission of light through material. She assigned students to light a candle and set it securely on a table. Students collected a variety of materials-glass, cardboard, wood, frosted glass, plastic, a clear rectangular container of water, etc. Napaporn told students to hold each of the materials between students' eyes and the candle, observed whether the light was transmitted through the material. After that students recorded their results. Each group presents their data in front of the room. Napaporn finished her class by introducing the terms transparent, translucent, and opaque. Students enjoyed doing her experiments (Napaporn's Classroom Observation#1: July, 2009). However, this lesson she did not engage students to learn the concept of "Energy is a property of many substances and is associated with light and the ways in which other types of energy can be converted into light, and the way in which light can be converted into heat energy."

To encourage the students to learn science concepts, Napaporn said that she always prepared interesting experiments for her students. She would like students to get the results of experiments that related on science concept. When researcher asked her about the relationship between light and energy, the result presented that Napaporn held an individual science concept. She could not link between concepts therefore in her practice, students learned only concept by concept, as evidence below.

Researcher: What science concept did you want your students to learn for this class?

Napaporn: It follows my lesson plan. I would like my students to understand the meaning and characteristics of light and they can understand these concepts through experiment.

Researcher: What did you mean about the meaning and characteristics of light? Could you explain me?

Napaporn: Yes, I could. Students should know about light is a form of energy that travels in waves. Light can travel in all directions from the source. No matter what the source is, light travels in a straight line.

Researcher: Does light travel through empty space where there is no air?

Napaporn: No, It does not.

Researcher: Why?

Napaporn: In vacuum space does not have air so light cannot travel because it does not have medium.

Researcher: You said that light is a form of energy. How the concept of light relates to the concept of energy?

Napaporn: Light needs to use energy. For example, when we turn light bulb, it uses electric power.

(Napaporn's Individual Interview#1: July, 2009)

Napaporn showed that she was confident to explain individual science concepts more than integrated or two or more concepts linked together. When the researcher asked about her understanding of characteristics of light, she explained that light traveling is in a straight line. From Napaporn's third and forth lessons, the result showed that Napaporn prepared these lessons very well in aspects of activities. She provided students many experiments relating to the concept of lenses and refraction, and the concept of sound and sound wave. With regard to Napaporn's practices, she explained to the students that when light moves through one material and into another material, the light ray can bend. The bending of light as it moved from one material into another was called refraction. There were students asked her if light travels in a straight line when it moves through material. Napaporn answered students that refraction happened when light could not pass through material and it then bent. As this situation happened in the class, it showed that Napaporn was confused on concept of characteristics of light and refraction. She still had problems explaining how to link two concepts.

Textbooks Are Main Sources for Science Knowledge

From interviewing Napaporn, she mentioned that students would learn scientific knowledge following science curriculum standard. When Napaporn prepared her lessons, she stated that she used various textbooks from private companies to gain science concept for teaching. School textbooks were not enough for science content. Therefore, Napaporn spent her own budget to buy textbooks for her studying and preparing. In addition, she explained that updating textbooks were very interesting in aspect of containing a lot of content and providing many student activities. As Napaporn wrote in her reflective journal,

> …I like to teach Science subject. I am very happy when I see my students enjoy doing the activities. Many times I have to use my own money preparing things for class. Sometime, I started to teach in topics that were new for me. I need to find good textbooks that have complete content and interesting activities. However, I still teach based on school textbook. But the textbooks do not explain clearly scientific content. Some parts of the textbooks even though teacher could not understand and how about students?
>
> (Napaporn's Reflective Journal #2: July, 2009)

From classroom observations, after Napaporn and her students conducted experiments and already got results. Their discussions were lead by Napaporn to formulate the conclusions. At the end of lessons, she concluded science content by having students write following her reading from the textbooks.

2. Napaporn Understanding and Practice about Pedagogical Knowledge

To present this section, Napaporn's understanding and practice about pedagogical knowledge were interpreted into five sub topics of understanding and practice in: knowledge of goals and purpose for teaching science; knowledge of instructional strategies for teaching science; knowledge of assessment in science; knowledge of learner and learning; and knowledge of curriculum. This study was in same period of time as Napaporn.

2.1 Understanding and Practice about Knowledge of Goal and Purpose of Teaching Science

Scientific Knowledge and Scientific Skills Are Major Goals for Teaching and Learning Science but Scientific Attitude as only Minor Goals

Initial Napaporn's understanding of setting teaching and learning goals and purposes. She said that after her class, students should understand and explain the concept of light and sound first and then the students practiced their scientific skills through conducting their experiments. Napaporn thought that only two aspects of goals and purposes for teaching and learning science were related to scientific knowledge and scientific skills consistent with the NSCS. Like Malai's result, Napaporn did not mention that students should understand how to apply scientific knowledge into their daily lives. Until the researcher asked her to explain more about her expectations for teaching and learning science, Napaporn told to the researcher that she also realized the students were not only getting learning science in classroom. They could learn science from outside the school and they should be motivated to bring their knowledge for solving the problems related with environment, local community, and society. However, this aspect of her goals and purposes were on a minor level of her expectation as she mentioned during interview below,

> …In my opinion, I think that students' understanding of scientific knowledge and having scientific skills are my major goals and purposes for teaching and learning science. I would like my students to pass school examinations and have high score in Science subject. If they can use their scientific knowledge for their daily lives such as being responsible for keeping living things safe and healthy, I would be happier. I think that is the result from students 'understanding science concept (Napaporn's Card Sorting #1: July, 2009).

To succeed, Napaporn's goals and purposes for teaching and learning science, she paid a lot of attentions to prepare science content for students.
With regard to Napaporn's teaching practices, the results showed that she also engaged students to think how to use their knowledge to maintain environment and local community. Students were provided opportunities to use science equipment when they conducted their experiments. They wrote hypothesizes, planned investigations, and made conclusions. At the end of discussion among Napaporn and

her students, she always gave examples of news or events to students for making decision such as the building of a highway passing through a national park.

Nature of Science Is Mentioned as Students' Requirement for Learning Science

Initially, Napaporn held both Constructivist and Positivist understandings of teaching and learning science in aspect of students' learning the Nature of Science. In order to clarify and expand her understanding of articulating goals and purposes for teaching and learning science, Napaporn was engaged in individual interview by card sorting. She selected one card representing her teaching style. Napaporn also mentioned that her practices focused more on providing students to learn science by doing science. They would learn scientific knowledge and understand the nature of science. Her answers indicated that Napaporn held positivist understandings about the nature of science. In Napaporn's understanding, science was a body of knowledge such as principles, laws, and theories and was similar to technology. A scientist was a person who had good imagination and creativity to create new ideas and they could explain very natural phenomena in the world. Therefore, science could be inventing or designing things. A scientific approach to knowledge was inquiry process. Napaporn mentioned that students should learn scientific process skills and they could provide time to conduct experiments followed scientific methods that should be a series of: setting hypotheses, making observation, doing experiments, and making conclusions about the results. However, Napaporn's understanding showed constructivist understandings for some aspects of the nature of science, such as tentativeness of science knowledge, the nature of scientific models, and the interrelationship between science and society. As evidence below,

> …More than scientific knowledge, students should have scientific skills therefore, I am very interested in preparing and providing experiments for my students. When the students understand science concept through investigations or experiments, they would know how scientists found the knowledge. I would like them to understand that scientific knowledge could be changed if there is

> new evidence that supports a new theory or principle. Sometime scientists need to build scientific models for explaining and representing natural phenomena that could not describe the whole reality as it is.
>
> (Napaporn's Reflective Journal #1: July, 2009)

With regard to Napaporn's classroom instruction, the finding revealed that her teaching was in agreement with her understanding. Her practice was consist with Napaporn's class as well, data from lesson plans, interviews, classroom observations, and reflective journals suggested that Napaporn's major goals and purposes of teaching science were to help students understood science content, have scientific skills, and understand the nature of science. However, Napaporn also focused that after students learned; they could explain natural phenomena and apply scientific understanding in their daily life. For students to develop environmentally based decision-making ethics and to have science attitude were set as peripheral goals and purposes for teaching and learning science. The way that she understood about the nature of science was different from Malai's thoughts. Napaporn then set some aspects of goals and purposes for teaching science that were different from Malai such as science evidences, decision making. Eventually, for a semester that she attended with CTM presented that Napaporn's understanding and practice for articulating goals and purposes were starting from students' learning science concept by doing experiments aligned the steps of science methods and they then would develop their life skill.

2.2 Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science

Classroom Lesson Introduction: Teacher Motivates Students' Interest and Curiosities by Asking Questions in Her Initially Inquiry Based Lesson Plans

Napaporn understood a good science teacher for elementary level should be motivator. The teacher should create interesting questions to stimulate students' curiosity. She mentioned that students were engaged in lessons properly when the teacher could create engaging questions. Napaporn thought a teacher should introduce an inquiry-based lesson by motivating students' interest. She noted stimulating students' curiosity through discussion. The interview data showed that Napaporn had done careful thinking about questions raised for discussions. She realized the questions should be related to students' everyday experiences. As Napaporn explained,

> …In this class, my students are asked with open-ended questions for motivating them to be interested in my lesson. The questions are related to students' experience in their daily lives. They could look around and see answers to the questions. I think students can answer if the questions relates to students' lives. When the students answer these questions, they might explain the concept. After that I should tell them it's something they're going to learn from the lesson . . .
>
> (Napaporn's interview #2: August, 2009)

With regard to Napaporn's teaching, the results indicated that her practice was aligned with his understanding. In practice, Napaporn began her inquiry-based lessons by motivating students' interest. The teacher used discussions and examples of some experiments to stimulate students' curiosity. As Napaporn wrote,

> For this lesson, I motivate students' interest by showing them the picture of two people blowing some bubbles. I also asked students what the students see from this picture. I think it's valuable for students to observe and predict. It's also important to let them know that they're going to do the same experiment as the picture.
>
> (Napaporn' reflection #2: August, 2009)

However, the findings showed in both understanding and practice, Napaporn did not connect students' interest to scientifically oriented questions. The teacher always formulated and told students about scientific questions without realizing the students' interests. She also did not ask students' prior knowledge in any of her lessons.

Investigation: Teacher Focuses on Inquiry Based Teaching and Learning Science through Experiments Devised By the Teacher, Students or Both Parties, However She Still Is More in Lecturing Way Mixed with Experiments

Napaporn thought that experimenting was the only approach appropriate for students to learn science. She thought searching information from learning resources and conducting experiments were a useful approach for studying science in inquiry-based teaching and learning. As Napaporn explained,

> …For teaching science, I would like my students to learn science through inquiry-based teaching and learning. Students would learn how to gain knowledge like scientists did. I think inquiry teaching is not only having students do experiments. The students should have the opportunity to search information from the websites based on what their interests are, and related to science concept. They then write a report. In my opinion that is inquiry-based teaching.
>
> (Napaporn's interview #2: August, 2009)

The lesson plans and written reflections data also supported Napaporn's understanding that experimentation and information searching were the way for learning science through inquiry-based teaching and learning. In her first and second lessons, Napaporn wanted students to do experiments. In the third and fourth lessons, she planned to have them observe demonstrations. However, Napaporn still maintained teacher centered more than student centered teaching. She reflected that she did not want students only to observe demonstrations. She would like her students to conduct experiments by themselves. However, time and materials were not enough. As

Napaporn wrote, “my lesson plans provide students opportunity to investigate through conducting experiments. However, some lessons I did not have enough time and material. I need to use demonstration. I want students to do an experiment rather than to observe the demonstration” (Napaporn’s reflection #3: August, 2009).

In her practice, the result showed that Napaporn’s understanding of the investigation process, that was an experiment could be developed by the teacher or students. Napaporn thought it was dependent on the difficulty of science concept and the complexity of experiments. As Napaporn stated,

> …My students were assigned to design their own investigation by group working if the lesson contained easy science concept and its experiments were not complex. If students study a concept that is related to their everyday lives or they used to learn the concept before, I might have them design the experiment. Conversely, if they learn a concept that isn’t found in their everyday experiences or they don’t know about the concept before, I would plan the experiment for them and sometime I just demonstrated that experiments.
>
> (Napaporn’s interview #1: July, 2009)

With regard to Napaporn’s teaching, the results showed that Napaporn’s practice was aligned with her understanding. In practice, Napaporn had students engaged in hands-on activities in some lessons. In the first and second lessons, students conducted experiments. In the third and forth lessons, students observed demonstrations and discussed the results in classroom. As Napaporn reflected, “I teach model the reflection of a sound wave using demonstrations. I show students how to create sound wave by moving a slinky. After the demonstration, students observe and discuss with me. I write the conclusion on board. (Napaporn’s reflection #4: September, 2009). However, both experiment and demonstration were devised by the teacher. Napaporn did not ask students to share ideas regarding the design of the investigations. Students were provided to present their data in front of classroom like Napaporn’s class. Napaporn then formulated conclusion for them

To meet this goal, she understood science teachers should ask students questions, and let students search for information after learning activities in the class. The students should then do tests to assess their understanding at the end of the class. These teaching sequences indicated that Napaporn' understandings of teaching were teacher-centered, in which the teachers had a major role. Napaporn understood that about 80 percent of teaching activities should be based on lectures and that teachers should have strong science content knowledge. For her, if the teachers held correct science conceptions, they would be able to delivery science concept to the students as evidenced below,

> …I always learn science concept from workshops because I think the students needed content-specialist teachers who understand the real science concept to help them pass school examinations. Science teachers should prepare content and activities especially experiments.
>
> (Napaporn's Reflective Journal #3: August, 2009)

Napaporn thought a teacher should introduce an inquiry-based lesson by motivating students' interest. Napaporn noted she typically stimulated students' curiosity using questioning, discussing, and interacting real things. The interview and classroom data showed that Napaporn implemented about questions raised for discussions. She thought the questions should be related to students' everyday experiences. Her instructional practice agreed with her understanding. Napaporn began her inquiry-based lessons by motivating students' interest. The teacher used a picture of an experiment to show students and had discussions with them for stimulating students' curiosity. However, the result from CTM I and CTM II showed in both understanding and practice, Napaporn did not focus to integrate students' interest to scientifically oriented questions. She also did not explore students' prior knowledge in any of her lessons but in individual interview the researcher asked her how she prepared her teaching. Napaporn also mentioned about students with different backgrounds and family and she had to prepare lessons that would not disturb to students' parent in aspect of finance. Even though Napaporn did not refer directly to students' prior knowledge, she realized that a student's prior knowledge was very important to her teaching. In her practice, it presented that Napaporn had understanding of students' prior knowledge but she did not know how to find it and how to integrate to her teaching.

Conclusion/Explanation: Students Are Provided Opportunity to Analyze Data and Formulate Conclusion; However, They Are under Teacher's Direction.

Napaporn understood that students should be responsible for analyzing data and formulating conclusions. However, Napaporn mentioned that it was difficult and took lot of time for students to analyze data and make conclusions on their own. The data of lesson plans and classroom observations also supported Napaporn's understanding and practice that she thought students were responsible for analyzing data and formulating conclusions. However, when she did not have enough time or her students could not formulate conclusions of experiments, Napaporn told the students about conclusions and had them write following her lecture. With regard to Napaporn's classroom instruction, the results showed that her practice agreed with her understanding. In practice, both Napaporn and her students analyzed data. Students made conclusions on their own in the first and second lessons; however, Napaporn's role was director for formulating the conclusion.

Communication: Teacher Provides Students Time for Sharing Data and Conclusions with Others; However, in Practice Students Communicate Only Their Data

Napaporn understood that students should share their data and conclusions with others. Napaporn said that typically in her class students communicated data and conclusions through presentation way. However, Napaporn also sometimes she could not have enough time for students 'presentation. Therefore, in her practice, Napaporn occasionally made conclusion without allowing the students to share their conclusions. As Napaporn explained,

> …Sometimes, I don’t have time. I finish my class by telling students the conclusion. I only ask them to hand in their work. I understand sharing student’s ideas are important but I don’t have time.
>
> (Napaporn’s Reflective Journal #1: July, 2009)

Napaporn’s classroom instruction, the finding revealed that her teaching partly agreed with her understanding. In Napaporn’s teaching practice, she provided students with the opportunity to communicate their data with other students. However, she did not have them share their conclusions in three of the lessons. Finally, Napaporn concluded the concept that they learned today on blackboard and having students write their conclusions in their lab books.

Group Work: Students Should Learn Science as Group Working. However, They Still Work Individually even though They Sit in Groups.

Napaporn understood that students were better able to learn science if they work, share, and talk in group. She thought that students had less competition when they learned in groups and they could help other to learn science concept as Napaporn explained “students will gain more knowledge when they learn in group work, students have less competition and they can share their ideas (Napaporn’s interview #1: July, 2009). Napaporn also indicated that she assigned students to work as group because of not enough materials for individual student to do experiment. With regard to Napaporn’s teaching practice, the finding revealed that her practice was aligned to her understanding. In practice, Napaporn had students learned and conduct experiments in groups. In four lessons, students learned science in groups. They conducted experiments, answered questions in their lab books, and formulated conclusions. There were 7-8 students per group. For Napaporn’s class, students sat together as groups but did not work together. Only 2-3 students did experiments and others just copied the results. In group, members were not assigned to have specific roles. Napaporn’s class, students were provided to work as group because of sharing experimental equipment. Napaporn did not assign individual students roles during group work or provide guidance on how to work cooperatively in groups. She also clustered students in groups by calling the students' names. Group sizes were large, therefore it was difficult that every students to talk and share their ideas.

2.3 Understanding and Practice about Knowledge of Science Curriculum

School-based Curriculum Is Integrated into Her Lessons Often as Framework for Teaching Goals, Science Concept, and Science Processes

"Learning and teaching science were based on school –based science curriculum because I developed it" This sentence was argued by Napaporn. She was one member of school-based science curriculum developers. Prior to the CTM, Napaporn had experience of developing the school-based science curriculum. Napaporn specifically noted that she knew there was a new science curriculum and she also developed her school-based science curriculum based on the new national science curriculum standard. As she mentioned this through individual interview,

> …The way that I developed school-based science curriculum was based on the national science curium and mixed with school and community contexts. When I prepare my lesson, I always study the national science curriculum standard in aspects of what science concepts and scientific processes the students should learn in their grade level. Mostly, I use school-based science curriculum as my reference for teaching and learning science because it was related to teaching and learning goals for school.
>
> (Napaporn's Individual Interview #1: July, 2009)

With regard to Napaporn's lesson plans and classroom observations, the results presented that her understanding and practice were consist; however, she did not note that students should be motivated to learn science in aspect of scientific attitude and attitude toward science as her goals. Even though the goals and purposes for teaching and learning science were in the school-based science curriculum it also stated that students should be curious person and perfect citizen for community and nation.

2.4 Understanding and Practice about Knowledge of Science Assessment in Science

Learning Assessment in Napaporn's Classroom Typically Includes Assignments and Worksheets, and Tests

Even though Napaporn expected the students to learn scientific knowledge, the methods of assessment she employed were not consistent with her intended learning outcomes. She used assignments and students' answers in worksheets to assess students' conceptual understanding; however she rarely made corrections or gave any feedback to students to develop their understanding of progression in student learning. Students' work was checked only for classroom participation. In addition, the assessment tools she employed were not related with her intended learning goals and purposes. For example in an experiment of the traveling of sound, the aims of learning were that students should be able to indicate what materials sound can travel through, to write up the steps of investigation, and to formulate the conclusion of the investigation. With regard to Napaporn's instructional practice, students were gained to do investigation following her instruction and they then recorded data from investigation. Napaporn provided students time to present their data from every group. They discussed the data lead by Napaporn. Students were tested by multiple choice tests. After her teaching, Napaporn was interviewed and she then stated that the students understood the concept of sound quite well as she checked their works and their scores from the test. When asked about what the alternative concepts of sound that students still have problem with and what scientific skills that the students learn from the experiment. Napaporn replied as below:

> ...I did not ask students question about what concept that they still have problems with and I check students' development of scientific skills through

> observation; however I do not have assessment form for recording students' behavior. I will probably use form to check their skills on next lesson.
>
> (Napaporn's Individual Interview #1: July, 2009)

As the statement above indicated even though Napaporn focused largely on students' conceptual understanding and students' development of scientific skills, the assessment methods were not fulfilling her goal of teaching students. The main concepts of the assignment did not examine some key aspects of Napaporn's goals and purpose for teaching science. In addition she was not sure whether students' answers for the questions on their tasks could give her information of students' conceptual understanding and students' development of scientific skills or that student always simply copied the assignment. As CTM I progressed, the result revealed that Napaporn used tests to assess student's conceptual understanding, she always mentioned that her students always were assessed their learning at the end of lesson by completing the tests. The formats of the test were multiple choice and fill-in-the blank questions.

In summary, Napaporn emphasized conceptual understanding and developing of scientific skills as her students' desired learning outcomes. The assessing tools that were used for assessment were paper tests or work sheets of assignments that clearly delineated the right answer. In addition, asking questions were often used when the teacher interacted with students during classroom observation. Napaporn was not very concerned as to how or why the students answered as they did, however she was more concerned about the correct responses from students. The requirement of the correct answers from students was considered to be more important than creating better questions to prompt student thinking.

2.5 Understanding and Practice about Knowledge of Learner and Learning

Students' Prior Knowledge Is Seldom Aware in Her Classrooms

According to her understandings of learning science, Napaporn thought that the students had a major role in learning activities. However, with regard to her practice, the results presented that she was seldom aware of the importance of students' prior conceptions and learning styles. This lack of awareness was evident in her first and second lesson plans about the concepts of light and light waves. Napaporn intended to teach the characteristics of light concept by assigning students to conduct experiments to understand the concept of the characteristics of light and the concept that light can be separated into colors. Prior to teaching this concept, there was no activity concerning a student's prior knowledge and learning. She did not probe what students' prior understanding of light beam and light ray. Napaporn's instructional teaching revealed that even though she understood that students were different in aspects of family background, experience, and level of learning abilities, she should have prepared activities in the lesson supporting the students' levels of ability. Her class was not consistent to her understanding. Napaporn did not even explore what knowledge or experience her students had it before they came to her class. She lacked an awareness of the importance of her students' prior knowledge.

Teacher Holds Understanding of Multiples Roles for Reformed Science Teachers, and Consistent to Her Practice

The findings showed that Napaporn understood that the role of the teacher in inquiry-based teaching and learning should be multiples. She mentioned that inquiry teacher had roles including motivator, activity director, guide, facilitator and lecturer. As Napaporn explained "I think inquiry-based teaching and learning should focus on student's role. I think the teacher should not be a main director in the classroom. The teacher should be a facilitator or an assistant. To take this role, the teacher should assist students in the learning such as providing learning resources . . . To be an assistant, I motivate students' interest. The learning activities especially providing students doing experiments are also in my mind" (Napaporn's interview #1: July, 2009).

During the first central meeting, the finding indicated that Napaporn understood that she was also a lecturer. As Napaporn stated,

Researcher: What do you understand about the student's learning?

Napaporn: In my opinion, students understand science concepts and can explain what they understand. Students should learn science by doing experiments. They gain knowledge from my explanation... The first role of student is good listener and lecturer. I will be their facilitator to help them when the students have some questions in the lesson.

(Napaporn's Central Meeting#1: July, 2009)

With regard to Napaporn's classroom instruction, the findings revealed that her practice considerably agreed with her understanding. In practice, Napaporn motivated students' interest, designed learning activities, guided students how to do the activities, and provided students learning materials, as evidenced in the excerpt below.

Napaporn: Light is a form of energy that travels in waves. If I toss a pebble into a pond, which direction do ripples travel?

Students: Circular direction.

Napaporn: Do they travel outward in all directions?

Students: Yes, they do.

Napaporn: Same things happen with light. Like the ripples, light travels outward in all directions from the source. The source might be a candle or a light bulb**.** What color did you see when you light the candle?

Students: Yellow, white

Napaporn: Have you seen the rainbow when a rain shower ends. They could start to break up, and the sun shines in a patch**?** What is sunshine color?

Students: White color

Napaporn: Why we saw many colors on the rainbow? So, today I prepare an experiment to find how we can create the rainbow. Each group will get soap solution and dip. The first step, you dip a wand in bubble solution and blow some bubbles. Group members observe a large bubble carefully. Please record if you see any colors on the bubble? The second step, other members please write down the colors that you see and group members discuss to find answer where the colors come from.

(Napaporn's classroom observation #1: July, 2009)

The written reflection data also supported that in teaching Napaporn played many roles. As Napaporn wrote, "In this lesson, I acted many roles. I motivated students' interest using questions and discussions. I sequenced questions for discussion; from easy to hard. I prepared these questions ahead of time. I also advised students how to answer the questions and I conclude the lesson by lecturing." (Napaporn's reflection #1: July, 2009).

The Roles of the Student Are Active Investigators

Napaporn's response during the first interview reflected that student's role in her understanding as active investigator. Students should be provided the opportunity to answer on the things they were interested in. She perceived that students should conduct experiments, share ideas through discussions, and make conclusions. As Napaporn explained,

…I think students are investigators. Students find the answers about things they want to know. For example, I want students to do an experiment. I raise questions and guide them until they state the term "white color of sunshine". I then introduce them to the experiment.

(Napaporn's interview #1: July, 2009)

Data from lesson plans also supported that Napaporn understood students as the ones who conduct experiments, share ideas in discussions, and make conclusions. As Napaporn wrote, ". . . 5) Students conduct an experiment and answer questions on a worksheet. Students discuss data and make conclusion of the experiment in groups. 6) Students communicate their data and conclusions to other . . ." (Napaporn's lesson plan #3: August, 2009). With regard to Napaporn's teachings, the finding showed that her practice was consistent with her understanding in some aspects. In practice, students were also active investigators however they had to conduct the experiments following Napaporn's instruction. They had time to share ideas with others in discussions. In the four times of classroom observations, Napaporn always provided students to do a hands-on investigation. Students learned the lesson by observing demonstrations and sharing ideas in discussions. However, students did not play the role of minds-on investigators. In her four lessons, Napaporn did not provide scientifically oriented questions for students and students did not analyze data on their own. Some lessons Napaporn did not have enough time therefore the students did not shared data, and evaluate and justify their conclusions with alternative conclusions. In addition, Napaporn did not connect the conclusions with students' prior knowledge.

3. Napaporn's Understanding and Practice about Knowledge of Context

Napaporn had the same understanding about knowledge of context as Malai. Napaporn indicated that community, school, and students' background should be realized to integrate in her teaching. From Napaporn's reflective journals and interviews, the result showed that she understood the student's family background. Every experiment, she would prepare some material or things for some students who had family had financial difficulty.

In Napaporn instructional practice, even though she realized that teaching and learning science related to contexts of community, school, and students were crucial to teaching success, she did not use any sources in community around the school in observed lessons. Students learned science only in classroom and did same activity, no activities involved to the students' different backgrounds. She was focused on a classroom environment that should be silence and students should pay more attention to do experiments and to listen what teacher would like them to do. Napaporn explained when students were quiet, it was easier to manage and control them. As Napaporn's interview,

> …During the classroom teaching, my knowledge about students' social backgrounds and living conditions in an agricultural setting helped me to identify specific teaching strategies and resources suitable to students' needs and interests. In addition, students' family background was an important factor for my teaching because some materials I have to prepare for them.
>
> (Napaporn's Interview 4# September, 2009)

Napaporn's Understanding and Practice of PCK After Participating in PCK-based CTM

In this section, the results are discussed in terms of Napaporn's PCK development through the activities in CTM. She had participated in the CTM from July 2009 until March 2010. The CTM was a long-term professional development. There were four stages of CTM (CTM I- CTM IV). For the second semester, Napaporn taught in lessons of Weather and Climate. These topics were Earth Atmosphere, Weather, Fog, Dew, Rain, Hailstone, and Climate. She started to prepare her lesson plan with other CTM members from November, 2009 after she participated in CTM II. Napaporn implemented the lessons by following the 5 Es inquiry process (DCIC and IPST, 2002). She used 5 Es like Malai. The 5Es inquiry process consists of five steps: engagement, exploration, explanation, elaboration, and evaluation. Napaporn's subsequence understanding of PCK was interpreted by various sources of data as mentioned in Malai. The development of knowledge bases is presented by considering aspects of PCK; understanding and practice of subject matter, understanding and practice of pedagogical knowledge, and understanding and practice of knowledge of context.

1. Napaporn's Understanding and Practice about Knowledge of Subject Matter

Before attending the CTM III, Napaporn was provided a chance to express what science unit or topics that she was not confident in teaching. In the second central meeting, when the researcher asked her to write these topics on a blackboard, she chose unit of Weather and Climate for using in CTM. What had changed Napaporn's understanding and practice about knowledge of subject matter? This question took almost one year to answer.

The Longer Time for CTM Participating, the More Learning New Science Content

At the second central meeting, Napaporn told CTM members about her lack of confidence in concept of weather and climate. As she mentioned,

> …I used to attend a workshop that integrated the concept of weather and climate into lesson plan. It did not explain in depth the concept. When I taught students, I always let students search information and gather into report. I am not confident to explain students what is the Earth's atmosphere I still do not know how many layers of it and how to identify?
>
> (Napaporn's Central Meeting # 2 November, 2009)

These sentences were supported by data from written reflection. In developing of lesson plans, Napaporn listed concepts of weather and climate that students should gain from her class. She brought these concepts to discuss with CTM members. The concepts were Earth's Atmosphere, Weather, Fog, Dew, Rain, Hailstone, and Climate. Since CTM II, the CTM members studied in national science curriculum standard and made framework for teaching of content. Napaporn shared her documents regarding science content of weather and climate to other members. They discussed about content and shared their ideas how to create inquiry-based lesson plans. As Napaporn said during interview "I learned what content I should teach in my class through my friends. They helped me to understand science curriculum and content of weather and climate such as, layers of the atmosphere are various categories depending on the criteria that were used to divide them. Now I could answer my students' questions of what layers of the atmosphere that jets cruise in" The first lesson that she co-taught with the researcher was the Earth's Atmosphere. The learning ways that Napaporn showed to CTM members were self study at home and sharing, discussing and reflecting on the concept with CTM members. In Napaporn's lesson plans, it showed that Napaporn's concepts of Weather and Climate were correct and related to NSCS. Consistent to Napaporn's' instructional practice, she taught students naturally.

Having Real Understanding in Science Concept therefore the Teacher Feels Confident to Explain How the Concepts Link

After Napaporn participated in CTM as one co-teacher, her confidence levels in explanation of science content were different from the past. As data from Napaporn's card sorting interview, she selected a card that had a teacher who taught concepts of weather. The teacher was in the card mentioned that the weather was different because temperature changed. Napaporn did agree with that content but she explained more detail. She explained that the land and water on Earth's surface absorbed heat energy from the sun. Some of this heat energy then warms the atmosphere above the surface. The amount of heat that is absorbed by Earth's surface and then released into the atmosphere changes from hour to hour and day to day. Therefore the temperature changed. (Napaporn's Card Sorting Interview#4 February, 2010). It was presented that Napaporn understood the reason why the temperature could change and she was very confident to explain more detail.

With regarding Napaporn's practice, she asked many questions to her class of students. These questions encouraged students to think about conceptual linking. Data from classroom observations, reflecting journals, and inquiry-based lesson plans reflected that Napaporn understood concepts of Weather and Climate very well. She could use daily examples to motivate students' interest. As the content was taught by

Napaporn “temperatures in the summer are warmer than temperatures in the winter. These differences are also caused by the position of the sun in the sky. In summer, the sun rises higher into the sky than it did in winter. So the sun’s rays are more concentrated on Earth’s surface on a summer day than a winter day. Different surfaces heat up at different rates. Grass heats up very slowly and does not hold heat well. That’s why grass feels cool to your bare feet on a hot day. Water heats up slowly but holds heat longer that grass. Roads, especially black tar roads, heat up quickly and can get very hot on a sunny day. They cool down quickly during the night. “This class, she asked students and showed them diagram of Earth and sun, pictures of grass and tar roads. Napaporn and her students and shared their ideas and discussed until they understood that content. I felt very relaxed and comfortable when I taught. Every step was smooth. Because when I was teaching in my class, it reminded me as I was discussing in the CTM meeting. So, I just conducted my class like I was talking with my CTM team. (Napaporn’s Classroom Observation #6: January, 2010).

With regard to Napaporn’s co-teaching, she and her co-teacher (Malai) taught about weather together. Napaporn asked groups of students to observe and measure the weather before class for 1 week. Students went outside and observed the weather. They used their senses to observe the weather such as eyes, ears, nose, tongue, and hands. Napaporn started the class (co-teaching with Malai) with interesting questions “have you ever struck your tongue out to let rain fall on it? Do you like the fresh smell in the air after a rain? Have you watched a flag flap in the wind? If so, you have been using your senses to observe the weather” Napaporn conducted her class interestingly and confidently. She integrated students’ daily lives into lessons uniquely. Corresponding to data from written reflections, the result was confirmed that Napaporn had more confidence in teaching. She developed her understanding and practice of subject matter knowledge.

2. Napaporn’s Understanding and Practice about Pedagogical Knowledge

The CTM designed by the researcher and was based on teachers’ data collected when they participated in CTM I. A total of thirty two weeks that Napaporn worked with other members as Malai did. She spent time together in sharing, reflecting, discussing, planning, teaching, and evaluating with CTM team. As the following paragraphs explain what Napaporn's progress on her understanding and practice about pedagogical knowledge during and after she engaged to CTM. There were five aspects of knowledge presenting Napaporn's changes in pedagogical knowledge.

2.1 Understanding and Practice about Knowledge of Goal and Purpose of Teaching Science

As the CTM progressed, some of Napaporn's articulating the goals and purpose for teaching science changed from the beginning, but other remained unchanged. She presented that her understanding and practice about this aspect of knowledge had developed since she was engaged in CTM.

Teacher Aims to Develop Students' Scientific Knowledge, Science Process Skills and Scientific Attitudes

Prior to the professional development experience, Napaporn understood the aims of teaching and learning science was to understand science concepts and to develop science process skills. In CTM II, she had an opportunity to compare her understanding and goals of teaching and learning science with the Science Curriculum Framework. Napaporn changed her understanding that students could learn science from hands-on with Mind-on activities. Students should participate in designing experiments, recording data, doing experiments, and searching for information. They did not need to do experiments relying only on scientific method. Rather, teachers might let students do experiments and make conclusions about the results which would lead them to understanding a scientific concept. They could learn a scientific concept and then verify the concept by doing an experiment. Napaporn's understanding about articulating goals and purposes for teaching science was enriched. She began to accept that she should focus to encourage student learning regarding understanding scientific knowledge; having science process skills; and holding scientific attitudes.

After Napaporn attended the third central meeting, she began to conceptualize the goal of science teaching and learning, as evidenced in the discussion of the CTM Team during the third meeting below.

Researcher: What do you intend your students to learn from your class

Napaporn: For me, the students should understand science content in this point I mean they can explain about weather and climate, conduct experiments by science process skills, and apply science knowledge into their daily lives. In addition, the students can explain how to get science knowledge or understand the nature of science.

Researcher: Could you describe us (CTM members) more about the nature of science?

Napaporn: Science knowledge is fact, theory, or law that can explain natural phenomena and science process skills are used for gathering the knowledge. The science knowledge can be changed if there was new evidence. Something happens with technology. No technology is ever a final solution. Technology can be improved and find new science knowledge.

Researcher: What else do you think your students should learn from your class?

Napaporn: Students can present and discuss what they learn from inquiry with other students. They can use this knowledge to make decision for their daily lives such as buying vegetables at the market, solving community pollution or maintain their high quality of lives in society.

(Napaporn's central meeting #3: December, 2009)

The data from her lesson plans showed that Napaporn wanted students to learn science by covering the three aspects. For scientific knowledge, she wanted students to understand weather and climate. In aspect of science process skills, she expected students to conduct experiments, make experimental conclusions, and select methods suitable for presenting data. With regard to scientific attitudes, Napaporn wanted students to use science knowledge for making decisions in their life's, community, and society. The students knew the way to stay peacefully and work collaboratively with others. With regard to Napaporn's teaching practice since she engaged CTM I to CTM II in the PD program, the findings showed that her practice was corresponding to her understanding. For scientific knowledge, Napaporn provided activities for students to learn weather and climate. For science process skills, Napaporn gave the students a chance to pose experimental questions, do the experiments, and make experimental conclusions. However, in her lessons for the CTM IV, Napaporn did not provide students opportunity to select a method suitable for presenting their data. Her co-teachers (Malai and Sirod) and she assigned students to write their data into a table provided for them. Napaporn indicated during the interviews that she was afraid that her students would not know how to present their data. However, Napaporn and other CTM members also discussed this point (Students' presentations) in the informal small group discussion. It encouraged Napaporn and her co-teachers to think that the students should have chance to try planning their own presentation methods. Consequently, the fourth and fifth lessons, Napaporn and her co-teachers (Malai and Sirod) opened time for students to create their own presentations. In terms of promoting scientific attitudes, Napaporn emphasized that students think how they could apply the science knowledge that they learned from the lessons for improving their lives. Students were assigned to write a journal about how the weather and climate affects them?

In summary, Napaporn came to the CTM with dualistic views about the nature, teaching and learning of science. She held both constructivist and positivist understanding and practice of PCK. Her understanding of goals and purposes for teaching science in aspect of the nature of science changes from science and technology was seen as the same thing; science became a subject to explain natural phenomena, that the scientific method is a step-by-step process. Therefore, learning is receiving information and teaching is giving lectures. As the CTM progressed, Napaporn understanding of PCK developed to become more constructivists in the concept of the nature of science, and goals of teaching and learning science in the Science Curriculum Framework. Students should hold three aspects of teaching and learning goals and purposes for Science subject, science knowledge, science process skills, and scientific attitude.

2.2 Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science

Classroom Lesson Introduction: Teacher Begins the Inquiry-based Lesson by Motivating Students' Curiosity, Clarifying Scientifically Oriented Questions, and Eliciting Students' Prior Knowledge

In CTM I, Napaporn understood that she should introduce an inquiry-based lesson by motivating students' interest. However, after participating in the CTM II- IV, Napaporn conceived that she should ask students' prior knowledge and also discuss with them about scientifically oriented questions.

After Napaporn attended the third central meeting, she designed an inquiry-based lesson plan, and implemented the lesson in her classroom in CTM IV, the data from interview and lesson plan showed that Napaporn came to accept that, besides motivating students' curiosity, she should also elucidate the main question students are expected to answer, as well as uncover their prior knowledge. Napaporn explained how she understood that students were interested in the scientifically oriented question since the question was derived from their ideas, as shown in evidence below.

Researcher: What is the main question that you want students to answer?

Napaporn: I would like students to understand the concept of weather and climate. In concept of temperature, energy from the sun heats the surface of Earth. The measure of that energy is called temperature. So the question is, “What are different temperatures in heating water and land?”

Researcher: Do you think students are interested in this question?

Napaporn: Yes I do because the question is from the students. I revise their questions. At first students ask me, “What happen with temperature if we put sand and water under lamp” and “What is going on if we measure temperature between heating sand and normal sand? I then adjust their questions into, “What are different temperatures in heating water and land?”

(Napaporn’s interview #7: December, 2009)

In the lesson plan, Napaporn raises an issue about current news to stimulate students’ interest in the concept. She then showed pictures of grass field, sand beach, tar road, and ocean. Napaporn motivated students through these pictures and interesting questions, for example, Where do you think you would feel cold under the sun and why?

After Napaporn experienced the CTM II and III, her understanding regarding the classroom lesson introduction was strengthened, as evidenced in the lesson plans, interviews, and central meetings. In her lesson plan of CTM III, Napaporn planned to motivate students’ interest in weather and climate, link the motivational activity to everyday experiences, and elicit students’ prior knowledge by having students write their understanding on paper.

The data from her lesson of CTM III also showed that Napaporn maintained her understanding regarding classroom lesson instruction. In her lesson, Napaporn and her co-teachers (Malai) planned to promote students’ curiosity by comparing the pictures. Napaporn provided students the opportunity to write their current knowledge on paper. Her response during the last interview showed that Napaporn tried to have students present their prior understanding in concept of temperature and pose questions to investigate. With regard to Napaporn’s teaching practice, the findings indicated that Napaporn's practice in the CTM I partially agreed with her understanding. However, after she had participated in CTM II- IV, her practice moved to focus on probing students' prior knowledge and motivating students' interest. She taught her lesson following with her understanding accordingly. After the professional development experience, Napaporn introduced her lessons of the three different phases by motivating students' interest, asking about students' prior knowledge, and guiding students to scientifically oriented questions.

Investigation: Hands-on Investigation Is Devised by Teacher, Students, or Both Parties

In CTM I, Napaporn understood that students should acquire knowledge through hands-on investigations. Napaporn understood students learned more when they physically engaged in natural phenomena. After Napaporn participated in the CTM, she maintained his initial understanding that students should acquire knowledge by conducting hands-on activities. Correspond to the data from her lesson plans, interviews, card sorting and central meetings showed that Napaporn maintained her initial understanding that in inquiry-based teaching and learning students should learn science through hands-on investigation. After she participated in CTM II, students were motivated to formulate scientifically oriented questions by doing experiments. As Napaporn explain in her written journal of her co-teaching "Students work in groups of 5-6 persons. They design their own investigation for understanding of the water in the air. After that students discuss together about the purpose of the experiment, experimental procedure, and the answers of the questions before the experiment. At the end of this class Napaporn provided students with the diagram of water cycle and asked students to work with members to study this diagram and explain the cycle through comparing with the investigation of water in the glass. (Napaporn's lesson plan #5: December, 2009)

With regard to Napaporn's understanding and practice, she presented continuously that students should be provided time to design their own investigations, As Napaporn responded "in this lesson (temperature), I think students designed the experiment. I guided them by giving them sand, water, pans, and lamp. Students planned to organize their own investigation to understand what different temperatures of sand and water. In addition, my co-teacher (Malai) and I also created a data table for students. However, students could adjust the data table related to their investigations. They had a chance to decide what they wanted to observe. (Napaporn's interview #7: December, 2009)

The data from her lesson plans of the CTM III and the CTM IV supported Napaporn's understanding in that the investigations could be developed by students and the teacher should acted as facilitator gradually. For four lessons during the CTM, the experiments were developed by the teacher or both the teacher and students. Napaporn provided the opportunity for students to design the experiment. In the lessons, students conducted the experiments on worksheets. However, Napaporn allowed students to select the degree of the angle of incidence they wanted to observe.

Conclusion/Explanation: Students Are Responsible for Analyzing Data and Formulating Conclusions. Teacher Is the Helper and Facilitator to Enhance Them Getting Science Concept

In the CTM I, Napaporn already mentioned that students should be provided chance for analyzing data and making conclusions. In addition, Napaporn did connect the conclusion (new understanding) with students' prior knowledge, for example, Napaporn showed students two glasses with water that was room temperature at the beginning of the class. She then put ice cubes in one of the glasses. Students were asked to write a description of what's going happen in next fifteen minutes. Therefore students wrote their answers in their worksheets. After the students and Napaporn formulated conclusion "water in the air is called water vapor. When the temperature goes down, the air becomes too cool to hold all of the water vapor. The process of water vapor turning into liquid water is called condensation", she brought some students' prior knowledge such as some students described that after fifteen minutes the table would be wet because water from the glass that had ice cubes. Napaporn asked students why it happened like that. The students were engaged to link the conclusion with their prior understanding and developed their knowledge related to scientific knowledge. Napaporn also learned to improve her questioning skill for helping students to generate their conclusions.

With regard to Napaporn' teaching practice, the research findings revealed that Napaporn's practice during the CTM I (exploration stage) was not in agreement with her understanding. Even though Napaporn understood students should analyze data and formulate conclusions, in practice, she and students analyzed data together. Napaporn then formulated conclusions for the students and had them write the conclusion into their worksheets. However, while attending the CTM, Napaporn's teaching practice was considerably aligned with her understanding; expect the last two lessons regarding about the concept of Fog, Dew, Rain, Hailstone and Climate where Napaporn did connect the new knowledge with students' prior knowledge. Her understanding of student's learning was gradually developing.

Her lessons and practices were consistent, Napaporn had students analyze data and make conclusions based on evidence gathered from the investigations. Napaporn guided students to analyze data and make conclusions by following a similar strategy as described previously in her understanding. After reaching a conclusion for the lesson in the CTM III, Napaporn did not connect the conclusion with students' prior knowledge even though she knew that she should. However, in the lessons of the CTM III, Napaporn linked the conclusion to both students' prior knowledge and to the related science concept.

Communication: Students Share Their Data and Conclusions with Others

Initially in CTM I, Napaporn understood that students should share their data and conclusions with others. After progressing of CTM, Napaporn still held the same notion regarding communication, however, she taught accordingly with her understanding. After experiencing the CTM II-IV, Napaporn still maintained her understanding in that students should share their data and conclusions with other students in the class and also gradually developed her instructional practice

Napaporn’s reflection of her lesson and practice during the CTM III and IV provided further evidence that Napaporn maintained her initial understanding, as illustrated below;

> …In the third central meeting, I think giving time for students to present their own data and ideas was very logically because the students can talk and help each other to understand what science concept is. Another meaning is proving students make communication with others.
>
> (Central meeting #3: December, 2009)

After Napaporn attended the CTM, she began to conceptualize that in addition to helping students learn to justify and evaluate their data and conclusions, communication was the best way to train students to listen and respect alternative thoughts. With regard to Napaporn’s instructional practice, the findings showed that in CTM I, Napaporn’s practice partially agreed with her understanding of student’s communication. In prior practice, students communicated only their data. They did not share their conclusions. However, after she was engaged in CTM II-IV, Napaporn’s teaching practice was aligned with her understanding. In her instructional practice, students had chances to share both data and conclusions with others, as illustrated in an excerpt below.

Napaporn:	Now I want you to select a representative of your group. Then the representative will write data from the experiment on the blackboard. Which group would like to be volunteered?
Students:	My group would like to be the volunteer
Napaporn:	O.K. So, group three will present their data as the first group. Every group please sends your member to write your own data and conclusion on blackboard.
Students:	(Students fill up the blackboard with their data.)

Napaporn: (Napaporn writes five questions on another board.)

Napaporn: Students, look at the questions on the board. Students, work in groups to answer these questions. (Napaporn reads the questions out loud.) Students, consult with friends in the group. Talk with your friends and look at your data. Try to answer the questions. I'll ask each group to share the answers . . .

Napaporn: Ok, group three; please come to present your data and conclusion. In addition, please tell the answers for five questions.

(Napaporn's classroom observation #5: January, 2009)

Group Work: Students Learn Science and Work Collaboratively in Group

In CTM I, Napaporn already understood that students should learn science in groups. She realized all members should have his/her role in the group. The students should be motivated to work collaboratively. Napaporn's knowledge regarding students' learning through social interaction was also broadened.

After experiencing the CTM II-IV, Napaporn began to understand the significance of students' learning through social interaction during group work, as evidenced in the discussion during the second meeting below.

Researcher: Do you know why your co-teacher (Sirod) suggested that your lessons should engage students to observe ice cubes in glasses as individuals and then had them talk in group?

Napaporn: Because the students can share, reflect, and discuss their ideas. Moreover, when they work together, they would be trained to work with others cooperatively. In the future, the students will be the high quality citizen and can live in harmony with other people.

(Napaporn's Central Meeting #3: December 2009)

Napaporn’s conversation during the third meeting and her written reflection also showed that she recognized that students’ interaction with the activity was successful when the group had an appropriate number of members. As Napaporn stated “students could learn science knowledge more when they were provided to work as a group. However, group size was very important factor for engaging students to work in the group”.

After Napaporn experienced the CTM, she learned how to address the problem of large groups. Instead of having two or three groups merge into one, Napaporn had the groups share equipment. Napaporn’s response during the last interview showed that she still maintained her understanding in that all group members should be part of their group’s work. As she mentioned “In the second lesson, I co-taught with Malai and we clustered students into group and there were six students per group. I saw that some students didn’t participate much in the experiment. It’s because each group had too many students. But in the next lesson that I shared my class with Sirod, the groups were smaller. So, students could participate in the activity” (Napaporn’s interview #11: February, 2010)

With regard to Napaporn’s teaching practice, the findings revealed that in the CTM I, her practice was not compliant with her understanding. In practice, even though students sat in groups, they learned as individuals. After Napaporn attended the CTM II-IV, her practice was agreeing with her understanding systematically. In her lessons during the teaching processes, Napaporn assigned students to learn in groups. Each group still contained students of mixed-gender and ability. Napaporn did assign roles and duties for individual students. According to classroom observations, it was found that in the lessons of the CTM III, almost all of the students participated in the activities. But, a number of students did not engage in the learning activities in the lesson of the CTM I. As Napaporn indicated previously, there were too many students in each group. A group had around 7-8 students.

Napaporn broadened her understanding of teaching strategies to become more student-centered from the activities provided in the CTM. She had opportunities to learn constructivist-based teaching strategies from the CTM members. Additionally, in her understanding, student classroom participation and hands-on and Mind-on activity were important characteristics of good teaching. In Week 19, Napaporn expressed her ideas about student-centered teaching in which students took roles and participated in learning activities. The students had a chance to do experiments instead of being given lectures. She felt they should do activities, think, present their ideas, exchange their ideas with peers, and react to things around them. The teachers should motivate students to think, and search out their prior knowledge before teaching.

2.3 Understanding and Practice about Knowledge of Science Curriculum

Sharing, Reflecting, and Discussing Motivates the Teacher to Learn More in Science Curriculum and Know Exactly How to Implement Curriculum into Classroom

In CTM II, she was asked to analyze goals of teaching and learning science in the National Education Act 1999, the Basic Education Curriculum, and the Science Curriculum Framework. Napaporn mentioned that she thought she knew quite well about science curriculum because she was school-based science curriculum developer, analyzing these documents helped her understood goals of teaching and learning science which intended students to learn science with virtue, happiness, and competence. She also learned educational technical terms in these documents such as “education” “teacher” and “learning standards”. However, Napaporn noted in her ideas expressed in classroom discussion that she was confused about learning stages. This confusion became clear when she had a discussion with the CTM team. In her understanding, the sharing, reflecting and discussing of opinions in the central meeting of CTM helped her better understand that the Act, the Basic Education Curriculum, and the Science Curriculum Framework were interrelated. Napaporn’s responses in the worksheet indicated that she had learned that there were four learning stages for basic education including stage 1 (grade 1-3), stage

2 (grade 4-6), stage 3(grade 7-9), and stage 4 (grade 10-12). Napaporn could see that science teaching and learning should be relied on learning standards in the Science Curriculum Framework. As she mentioned “even thorough I had experience in developing school-based curriculum, I did not clearly know the Act and the Science Curriculum Framework. Since I participated in CTM, I learned what part of these documents I should use for my lesson” (Napaporn’s interview #7: December, 2009).

School-based Curriculum Is Used as Lesson’s Framework in Aspects of Goal, Content, and Process Skills that Students Must Learn in Each Grade Level

In CTM I, Napaporn focused on school-based curriculum for developing her lesson. She mentioned that students should learn science based on the national requirement and related with school goals. After she was engaged continuously in CTM II until CTM IV, Napaporn still had the same understanding of using school-based curriculum for her developing of inquiry-base lesson plan.

In first interview and central meeting, Napaporn mentioned that the school developed its own curriculum and this was aligned with the basic education curriculum and covered eight learning strands. In general elementary school, the students learned science during grades 1-6, however the students in the schools that she worked with did not learn the science area divided into main areas; biology, physics or chemistry. She now understood that the school-based science curriculum could be developed by the processes of planning, design, implementation and evaluation of the programmers of students’ learning by the school. The school-based curriculum should be related to school context. This understanding was evidenced in her written reflection:

> …School is part of a local education authority and a national educational system. The science teachers should have good understanding of the national and school-based curriculum and their instructional practices must be related to both curriculum. For my experience, I think that school-based curriculum

relates to community bodies. Therefore, the curriculum should not be parochially conceived.

(Napaporn's Written Reflection# 2: August, 2009)

In summary, initially Napaporn's knowledge of science curriculum was good since she had learned about the school-based science curriculum development before. When reading and discussing the content in the National Education Act 1999, the Basic Education Curriculum, and the Science Curriculum Framework, Napaporn could share her experiences of curriculum development and it encouraged other CTM members to be interested in the science curriculum. However, the way that Napaporn brought school-based curriculum to implement in her class was not in agreement with her understanding in aspects of teaching and learning goals. Most of her lesson in CTM I focused on only students gaining knowledge and having science process skills.

2.4 Understanding and Practice about Knowledge of Assessment in Science

Napaporn Has Developed Her Knowledge of Assessment, Including Dimensions of Student Learning and Methods of Assessment

Initially, Napaporn understood about student conceptual understanding and science process skills as student learning outcomes and concept tests as main assessment methods. At the beginning of the CTM, Napaporn's goal of teaching science was to help students understand science concept. Napaporn's expectation of student learning was evidenced in her first lesson plan about light and sound. She intended students to be able to tell the meaning of light and its characteristics. These learning outcomes were content-specific, but did not cover all dimension of student learning such as procedural and social aspects. She assessed student learning using concept tests. She asked students to complete a test after the lesson.

However, after Napaporn continuously participated in CTM II-IV, the results from central meeting, lesson plans, interview, and classroom observations showed that as the CTM progressed, Napaporn gradually developed her knowledge of assessment. She had developed an understanding of various dimensions of student learning and methods of assessment. When she analyzed and discussed the content in the National Education Act, the Basic Education Curriculum, and the Science Curriculum Framework, Napaporn found that learning science should also focus on ethics and morals in addition to science conceptions. In her understanding, students should develop their inquiry processes and scientific mind. After sharing, reflecting, and discussing of ideas, knowledge, and teaching practice among CTM members through video of teaching in CTM II, Napaporn reflected on her understanding of formative assessment in her written reflection, commenting that assessment of student learning was an ongoing process occurring throughout learning and teaching activities. Students were assessed at the beginning or the end of the teaching class. Napaporn also discussed the assessment methods that should be variety for assessing student learning in the classroom. As she said "I always use only multiple choices test for probing students' learning because I think that is easy way to assess. When I discuses with you (CTM members), I have learned that not only multiple choices test for midterm and final test is available for students. Students should be evaluated and assessed through many ways and by many persons, not only teacher. Teachers should use variety of assessment methods. Especially, authentic assessment should be integrated into class. (Napaporn's Central Meeting#2: November, 2009)

In CTM III, Napaporn applied her understanding of assessment in her microteaching about weather and climate. The students learning outcomes covered three dimensions of student learning and were content-specific, science process skills, and scientific attitude. Napaporn intended students to do an experiment about explaining Earth's atmosphere, weather, severe weather, and climate and work cooperatively. To assess student learning outcomes, Napaporn use multiple choice tests but she also asked students about reason. In addition, she also used observation during student activities; developed worksheets related to Earth's atmosphere, weather, severe weather, and climate; provided a chance for students to assess their group members in aspect of sharing and working in a group; and assigned students to do practical homework.

With regard to Napaporn practices, the results showed that her knowledge that was used to create her lesson plans was aligned with her instructional teaching. When she taught students the concept of the Earth's atmosphere, she assessed students using the methods that were mentioned in her microteaching in CTM III. Napaporn also used concept mapping to probe students' learning with the last lesson plan of climate concept. From interview data, inquiry-based lesson plans, card sorting, and classroom observation, the results revealed that her expectations of students' learning in science were covered in three aspects, science content, science process skills, and scientific attitude. Consequently, Napaporn used various types of assessments methods such as test, member checking, written journal, drawing, practical homework or concept mapping to evaluate students' understanding science.

In summary, initially, Napaporn had limited understanding of assessment. For her, conceptual understanding was main purpose of teaching and learning science. In her first lesson plan during CTM I, Napaporn rarely focused on other dimensions of student learning such as procedural and social aspects of learning. She employed only a science concept test as an assessment tool. As the CTM progressed, Napaporn's assessment knowledge developed from discussion of goals of teaching and learning science in Science Curriculum Framework, and reflection on science teacher's teaching. Three aspects of student learning including conceptual understanding, science process skills, and cooperative learning appeared in the fifth lesson. Napaporn‘s assessment methods were corresponding to her goals and purpose for teaching and learning of science. Content-specific various assessment methods were employed, for example, a concept test, observation, worksheet, evaluation form of cooperative learning, and practical homework.

2.5 Understanding and Practice about Knowledge of Learner and Learning

Napaporn's Knowledge of Student Conceptions and Learning Is Developed from Classroom Discussion and School-based Activities

As the CTM progressed, Napaporn gradually realized the significance of students' prior conceptions and learning. This understanding was developed from many activities in the CTM. For example in CTM II and III, she had a chance to share and discuss about student learning aligned with the Science Curriculum Framework. She noted that student learning was important in classroom teaching. She was also motivated to share ideas about prerequisite concept for learning about weather and climate. In her understanding, students should have basic conceptions in wind and energy. In CTM III, Napaporn had opportunities to read articles about student alternative conceptions in science and their learning difficulties, and then discussed these with her co-teacher. In small group discussion, Napaporn reflected on her understanding as "teachers should be aware of student ideas, and hear their ideas and understand students' needs. Teaching and learning should be based on student's ability. Every lesson conclusions were linked to students' prior knowledge. The way that a teacher could deal with student's prior understanding was categorizing student's prior understanding of the concept of weather and climate and have the students and teacher made a conclusion. The teacher could ask the students to develop their understandings of the science concept.

With regard to Napaporn's practice, the result showed that she spent time probing students' prior knowledge or experience of the concept of weather and climate. Her understanding was compliant to her practice. As evidence below,

Napaporn: Could you draw about Earth's atmosphere as you understand on A4 paper.

Students: Do I need a description on my picture?

Napaporn: Yes, you do. If someone would like to paint the picture, you can do also.

(Napaporn's Classroom Observation#5: January, 2010)

Napaporn also had learned about student conceptions and learning from co-planning with her co-teachers during the progress of CTM. She reflected on her learning with CTM team that most elementary school students had difficulties in learning about imagination concept.

The Role of the Student: Student Is Active and Minds-on Investigator

In CTM I, Napaporn's understanding about teachers' role was broadened. She understood teachers as activity organizers who prepared teaching and learning activities that encouraged student learning. For her, the science teachers had the responsibility to organize science content and learning activities to meet student interests and ability.

In attending the CTM I, Napaporn understood the student role as active investigator. However, she still maintained her role as major in the class more than students' roles. After she participated in the CTM II-IV, her understanding of the student role had developed from positivist to constructivism view. Napaporn conceptualized the role of the student as active and minds-on investigator She presented that students should involved in discussions, conduct hands-on activities, think critically and logically of the activities, and significantly know problems or questions that the activities intended to address. The teacher should provide the major role in learning for students. After Napaporn attended the third central meeting, she designed an inquiry-based lesson plan, and engaged in the CTM IV she taught the lesson, she began to develop her understanding and changed her teaching practice. Napaporn presented that teaching and learning by inquiry-based approach, the role of students as active and minds-on investigators, as reflected in her written reflection and interview. Napaporn stated, "If you would like to teach science through inquiry-based teaching and learning, the teacher should provide the role of the students as the main persons in investigation, conclusion, and discussion. Students should learn about what they are interested in" (Napaporn's interview #2: November, 2009).

Napaporn's response during the last interview also highlighted her notion of the student role as active and minds-on investigator. As Napaporn considered, "Students are those who engage in hands-on activities. They know questions that the experiment intends to answer. They also present and discuss their data" (Napaporn's interview #4: February, 2009).

With regard to Napaporn's teaching practice both before and after the professional development program, the findings revealed that her practice was aligned with her understanding. In her lessons during the CTM I, students played the role of active investigator. After Napaporn engaged in the CTM, Napaporn provided students lessons with focusing both physically active and minds-on investigators compliant with her understanding. Students were encouraged to participate in formulate scientifically oriented questions, discussions, conduct hands-on activities, and think logically and critically of the activities they did, particularly in terms of problems or questions to investigate. She also motivated students to think critically of the reasons behind their actions, as evidenced in an excerpt below.

Napaporn:	What did you conduct as an investigation?
Students:	My group used pans of water and sand to represent the ocean and the land. We used the same amount of water and sand.
Napaporn:	Do any group do something else?
Students:	My group took the temperature of the water and the sand. We recorded each temperature and we made sure that both pans had temperature about the same.
Napaporn:	Why do we have to use the same amount of water and sand? For the second group also make sure that the temperature of water and sand start at about the same temperature before put it under lamp?
Students:	I think when we did like that; we will not get result error. We use the same amount of water and sand therefore they get heated by lamp at the same level.

(Napaporn's classroom observation #6 January, 2010)

The reflection data supported that the student role in Napaporn's teaching practice was that of active and Mind-on investigator. After CTM II-IV experience, Students were provided to learn science in aspect of Hand-on and Mind-on activity.

The Role of the Teacher: Teacher Plays Multiple Roles

Initially, Napaporn conceived that the teacher had multiple roles in an inquiry-based classroom. These roles were comprised of guide, facilitator, motivator, activity director and lecturer. Throughout her engagement in the CTM, Napaporn maintained the notion regarding the multiple roles of the teacher, however, after Napaporn attended the second central meeting, preparing knowledge for developing inquiry-based lesson plans in CTM III. Napaporn mentioned that she still held the same understanding that the teacher had multiple roles. The teacher could play any role depending on classroom situation. The main purpose of the roles was enhancing students' interest in topic actively and conducting their investigation through inquiry. As Napaporn wrote in her journal "In my class, I always allow students to plan their own investigation, however, if they cannot design a plan by themselves, I guide them by questioning or providing them a framework" (Napaporn's written reflection #16: January, 2010). The data reflected that Napaporn shifted her focus regarding the role of students that relied on learner-centered approach.

Napaporn's understanding of the role of the teacher and student was enriched. Her practices agreed with her understanding also. As Napaporn explained:

> …I think for four inquiry-based lesson plans that I co-planned with my co-teachers covering many roles of the teacher. I designed the learning activities and discussed with my students how to do the activities. After we discussed and got the main question for our investigation, I posed the questions and motivated students to be interested in the questions . . . I provided student's

> opportunity to plan the investigation and analyze data gathered from textbooks and worksheets. Students were asked to answer my questions by using their prior knowledge combined with information from the learning resources. I wrote their answers that they studied from textbook and worksheets on the board and guided them in how to answer the main questions appropriately. The students were guided by the teacher to discuss the data and formulate conclusion. I guided them to understand the data that they got from their investigations. I didn't tell them the conclusion. I asked students to present their data and conclusions.
>
> (Napaporn's interview #11: February, 2010)

With regard to Napaporn's instructional practice since CTM I to CTM IV experience, the research findings presented that her practice aligned with her understanding. In CTM IV, Napaporn performed multiple roles in her inquiry-based classrooms. These were motivator, activity director, guide, and facilitator. However, Napaporn sometimes used lecturer role in her classroom when students tried to formulate conclusion and they did not have enough time. After professional development, Napaporn did not teach scientific knowledge before asking students to conduct the investigation. Napaporn motivated students' interest, provided questions to investigate, guided students investigational procedures, advised them how to do the investigations, and facilitated students in how to analyze data and formulate conclusions. In her class, students mainly were provided learning material from Napaporn.

3. Napaporn's Understanding and Practice about Knowledge of Context

School and Community Contexts Are Integrated into Her Teaching Activities

In CTM I-IV, the results showed that Napaporn created several activities in worksheets related to students' local communities according to suggestions that came from the CTM group. She used knowledge of content as Malai did with her teaching.

Napaporn was the advisor for Malai for integrating school and local context into lesson plans. Students were provided activities relating reading news, events, or articles that happened in students' local communities. After that the students would share their ideas with other students in class. Napaporn used these activities for engaging students' curiosities and promoting students' thinking.

With regard to Napaporn's instructional practices, she engaged students by asking the questions that were related to their context e.g. "how does weather affects living and non-living things in your local community? What is your local weather forecast? Napaporn mentioned that when she asked students these questions, students were very interested in the activities and questions. They could go back to home and discuss the questions. They then shared their information as a group. Napaporn agreed with Malai's thought during a meeting among the CTM team that learning science does not happen only in classroom. Students could understand and learn science more when they have chance to interact with others (Napaporn's Central Meeting# 5: February, 2010).

Providing Scientifically Environment in the Classroom to Motivate Student Learning

Napaporn gained ideas from Malai about providing students a scientific environment in the classroom to enhance students to learn more about science. Regarding to Napaporn's written reflection, the results presented that she understood that the classroom atmosphere was an important encouraging factor on students' curiosities, as she expressed "My students were very excited to learn in a decorated classroom. Malai and I helped each other to design what classroom we would like to have during our co-teaching. I also put the students' work on the board as well. They could learn from each other and they should be proud of themselves when they saw an individual or groups work shown on the board. (Napaporn's Written Reflection#14: January, 2010).

Napaporn presents her understanding in CTM meeting that she would like to make the room attractive and functional for engaging student learning in science subject. Her understanding agreed to Malai's understanding. Napaporn did not mention about making scientific environment to engage student's learning in CTM I (Exploration Stage) until participating in CTM II, Napaporn stated that teachers should consider grade/age level appropriateness, the type of classroom activities the teachers would be implementing, and their particular style. Not only co-teaching with Malai, Napaporn also co-taught with Sirod and they focused to prepare the classroom for their students.

The first co-teaching between Napaporn and Sirod revealed that they helped each other to organize their classroom. The first day of co-teaching between Napaporn and Sirod, students were assigned to work in groups. While Napaporn co-taught with Sirod, students were asked to interact by reading posters on the wall when they finished discussion and conclusion of that class (Napaporn's Classroom Observation# 5: January, 2010).

Napaporn's developments of her understanding and practice of PCK was gradually changing based on constructivist teaching and learning. Her understanding was systematically and corresponds to her instructional practice. Napaporn revealed that providing her an opportunity to have a team for sharing, reflecting, and discussing in CTM was an effective professional development tool on the development of her knowledge. She commented that CTM should be used as a PD program in school. In addition, the program should be supported by university in aspect of working with experts in faculty of science or faculty of education.

Summary of Napaporn's PCK Development throughout the PCK-based CTM

At the beginning of the CTM (Exploration Stage), Napaporn held positivist understandings of teaching and learning science. Her understanding of how to gain scientific knowledge was to receive information by various methods such as listening, speaking, reading, and writing. Students could learn science content and scientific skills from doing experiments, and from real situations in their everyday lives. Inquiry-based teaching and learning was the best way to promote students' understanding of scientific knowledge. From her understanding of students' learning, Napaporn's engaged students' to learn science through doing experiments. The students needed to follow procedures aligned with the scientific method, meaning students have to follow the steps of: setting hypotheses, making observation, doing experiments, and making conclusions about the results. They could not skip any steps, and had to obtain the result from experiments related to the science concept. In CTM Napaporn initial understanding about the nature, teaching and learning of science were centered on positivist understanding. In her understanding, science is a subject that can explain natural phenomena, the scientific method is a step-by-step process, but scientific knowledge could be changed. Learning is receiving information and teaching is giving lectures.

Initially, her prior PCK for teaching science was limited. She was unaware of the importance of a student's prior knowledge. Napaporn's incomplete science content knowledge influenced her lack of awareness of student conceptions and learning, and resulted in a struggle in planning and teaching based on the constructivist-based teaching. Napaporn held a partial understanding of assessment in which conceptual understanding was main idea of teaching and learning science and concept tests were a good assessment method. With regard to Napaporn's practice, she always prepared experimental instructions for students before they started her class. Some lessons, Napaporn also demonstrated how to do investigation or experiment first and students then follow or copied what she did. Napaporn's teaching and learning Science was dualistic between teacher- centered and student-centered way. Many things she understood related to teaching and learning followed students-centered way, however, she implemented her lessons trendily to teacher-centered atmosphere.

After, Napaporn continued to participate in CTM II-IV, the result from reflections written by Napaporn indicated that she held a relatively understanding of effective teaching. She focused on other aspects such as student prior conceptions, learning, assessment, and hands-on with minds-on activities. As the CTM progressed, Napaporn's PCK developed. Through analyzing and discussion about the concept of the nature of science, and goals of teaching and learning science in the National Education Act 1999, the Basic Education Curriculum, and the Science Curriculum Framework, Napaporn's understanding about the nature of science to be more constructivist understanding. In her understanding, teaching science could be hands-on and minds-on activity, and could also be transmission of knowledge. From analyzing and discussing about the Science Curriculum Framework, Napaporn also developed her understanding about science curriculum and assessment. She had learned learning standards in the Science Curriculum Framework and came to understand more about goals and objectives in learning science was more focused in the science process skills and social aspects. Napaporn included science process skills, and cooperative learning as learning outcomes in addition to conceptual understanding. She used a variety of content-specific assessment methods such as concept tests, observation, worksheets, an evaluation form of cooperative learning, and practical homework.

The connection between school-based and classroom-based activities helped Napaporn understand more about the science curriculum and knowledge of student prior knowledge and learning style. Napaporn developed her understanding of the importance of student prior knowledge, prerequisite concept and causes of student learning difficulties. Through the central meeting of CTM, Napaporn's knowledge of teaching strategies improved. She had more understanding of pedagogical sequences of constructivist-based teaching in which hands-on activity and student ideas and conception were key ideas of a student-centered teaching approach. The CTM also enhanced Napaporn's understanding of the integration of knowledge bases [PCK].

The Case Study of Sirod

Sirod's Background Information

Sirod was a 38 year old man. He had 1 year and 11 months of science teaching experience leading into the 2009 academic year. For the 1 year of experience he taught science in the secondary level and 4 months teaching experience with the grade 6^{th} level. Sirod taught at Wattanawan School, a public school which is funded by the government. He completed a Bachelor's degree of Agricultural Education from government universities in the province of Bangkok.

In the 2009 academic year, Sirod had 20 hours a week of teaching responsibility. He spent 12 hours teaching General Science in 6^{th} grade. For the remaining 8 hours devoted to Activities Club, Scouts, and classroom counseling. The teacher indicated his non-teaching assignments to include being a homeroom teacher, member of the administrative section, member of the school activity section, and member of the audiovisual section. Sirod mentioned that his non-teaching assignments had taken more time than his teaching responsibility. During the past five years, Sirod had attended several workshops provided by educational institutions and his school. These workshops focused on curriculum, lesson plan, instructional media, teaching method, science content and learning and teaching assessment. His anxieties included a lack of learning materials, a lack of time for covering all science concepts, and a lack of some science content knowledge. Sirod expressed his reason for participation in the CTM. He knew that inquiry-based teaching and learning was an effective approach for teaching and learning science. To participate in the CTM, Sirod hoped to learn new techniques and/or strategies for teaching science through inquiry and know how to assess student's learning abilities.

Sirod said that most of these workshops were set on weekdays therefore he needed to leave his classroom with other teachers who were not science teachers (e.g., Math teachers or English teacher). Sirod said that he had limited time for preparing his lesson plans and his teaching. For school curriculum, his responsibility is only selecting the books and making lesson plans that are taught following the school curriculum.

In the first interview by card sorting, Sirod chose a card that represented his teaching styles in the Science subject. He taught science by having students do activities and providing them lecturing and worksheets that he prepared. The students read from a textbook and completed his worksheet. Sirod also mentioned about teaching science by letting students do experiments. He explained to the students how to conduct the experiments and the students then conducted explorations following his instruction, the students concluded by writing reports. He lectured students before and after the experiments. In classroom observations, Sirod began his class by telling the concepts that he taught previous. He concluded the previous concepts by lecturing on blackboard and having the students write these conceptions into their notebooks.

When coming to the PCK-based CTM, Sirod expected to learn: teaching skills, examples of teaching strategies integrating with science content, teaching strategies that made students learn by themselves and apply their knowledge into their daily lives, activities that can cover the content students need to learn, and various assessment methods for understanding student's learning. His expectations were almost same as Malai's and Napaporn's but he also would like to improve his assessment knowledge of student's learning. Throughout the CTM, Sirod was open-minded regarding his involvement in classroom discussion and reflection in journal entries. He often expressed his feelings directly to the CTM instructor and to his peers.

Students' Background

In this study, classroom observations were conducted with a class of 6th grade students. These were 40 students, comprised of 23 females and 17 males. Most of the students were from working-class families and lived residentially in the vicinity of school. Many of the students had an average to low achievement scores in science.

The average grade was 2.5-3 from a scale zero to four while the students were in 5th grade.

In the first interview, Sirod expressed that he lacked basic knowledge for teaching science. He was concerned that he did not enough science knowledge to teach students and the students would have problem with district and school examinations. In addition, the students did not have science process skills and had less experience in science therefore Sirod had problems when he started to have discussions with them. They could not share their thoughts and answers. Sirod had to tell them the right answers. Sirod presented his understanding that to be successful in learning science the students needed basic knowledge about the concepts of study and learning scientific skills. Most of the students in the classroom had financial problems. Parents could not provide enough materials for learning in science. As a result, Sirod had to purchase teaching and learning materials for the students from his own personal budget. He revealed that he could not prepare the materials for every student.

From classroom observations, Sirod and his students had a good relationship in and outside the classroom. He expressed that he represented himself as a students' friend. The students could come and consulted him anytime. He always used informal language with the students in his classroom therefore they did not feel uncomfortable with him.

Classroom Context

In this study, the observations of Sirod's instructional practices were conducted in classroom. The 6th graders' classroom was a middle sized room. The classroom was same as Malai's classroom. The students' seats were organized in three columns. There was one blackboard and one white board permanently connected to the wall in the front of the room. A teacher's desk was situated nearby the blackboard. Windows were located along the right side of the room. There were no decorations on the walls of the room. There was a television in the room, but it was never used for teaching. Three bookshelves filled with textbooks were placed in the back of the room. Items donated by the students and their parents were also placed in this area. There were two boards filled with announcements, and students' works. During classroom observations, the researcher located himself to the back of the room close to the window. A layout of Mr. Sirod's classroom is displayed in Figure 4.3

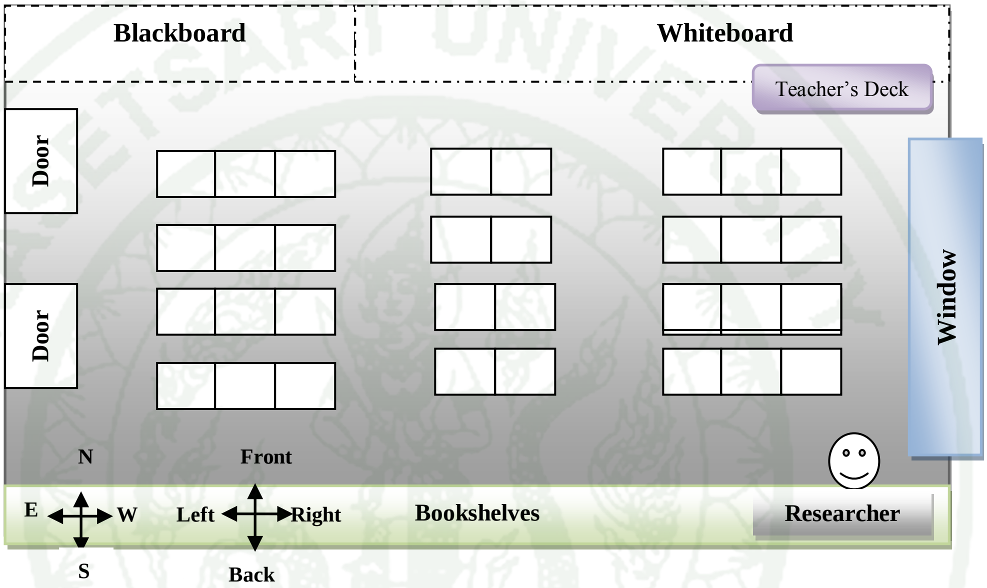

Figure 4.3 Layout of Sirod's Classroom in 6th Grade

Sirod's Understanding and Practice of PCK Before Participating in PCK-based CTM

This section presents results from the exploration phase: CTM I- the preparation phase: CTM II. The researcher interviewed three teachers individually regarding his/his understanding and practice of PCK. Sirod was observed by the researcher in the classroom that the teacher implemented inquiry-based lesson plans created on his initial understanding of inquiry-based teaching and learning. The instructions were observed and recorded by VDO recorder. Sirod's unit was Ecology and his lesson plans were: 1) Biotic and abiotic; 2) Organism, Population, 3) Community; and 4) Food Chain and Food Web. After implementing each lesson, Sirod then wrote a reflection of his lesson plans and teaching experiences to share and discuss with the CTM team in the first central meeting (Activity II) at Kasetsart University. Sirod's prior understanding and practice of PCK was analyzed from multiple data sources individual interviews, card sorting, classroom observations, teachers' written reflections, teacher's initial inquiry-based lesson plans, and the first central meeting. The data was analyzed and presented by case study individually. The prior understanding and practice of PCK is expressed into three main aspects of essential features of PCK.

1. Sirod's Understanding and Practice about Knowledge of Subject Matter

Teacher Lacks of Science Content Knowledge

In CTM I, Sirod intended in sharing his lesson and classroom to develop his PCK. In the first interview, Sirod mentioned explicitly that he did not have any science knowledge background. He had to teach science because the school did not have enough science teachers for elementary level. In the first observation, when Sirod's starting his teaching, he expressed his feelings of being uncomfortable about science content in topic of ecosystems. Even though he did not graduate in science, he would like the students learn science by doing. During card sorting Sirod expressed that he still had alternative conception of ecosystem. He could not explain relationship among species, organism, population, and community as evidence below:

Sirod:	Last week we learn about habitats. Habitat is the specific environment that meets an organism's needs.
Students:	Could we call the three as habitat?
Sirod:	Yes, we can. The tree in the forest provides shelter and a source of food for insects, birds, and lizards. The role organisms play in the habitat is called a niche.
Students:	Does the habitat need to have only one organism?
Sirod:	Each kind of habitat meets the needs of a different mix of species. So, the habitat has more than one species.

Students: Are species and organism same?

Sirod: Yes, they are living things in the habitat.

(Sirod's Classroom Observation 1#: July, 2009)

With regard to his understanding of science content and his confidence to teach science aligned with his practice in classroom. Sirod still did not have enough science content knowledge and he did not have access to sources where he could learn science content. From Sirod's perspective, he understood that his ability to teach science concepts would be better if he knew more science knowledge. He felt very confident to teach Agricultural Subject more than science. As Sirod mentioned "I want to make sure that students learn complete science concepts from me. However, I do not have strong content. Most of my teaching was based on teaching manual books. I have to prepare content before my first lesson because I am not confident to answer students' questions and I need to improve my knowledge" (Sirod's Interview#1: July, 2009)

Every interview that happened while Sirod participated in CTM I (exploration stage), Sirod and Malai presented that they did not have strong background in science. In the first card sorting, Sirod selected the lecturing teacher as his teaching style. He said that he would teach students like that but he would provide students the opportunity to conduct investigations. For his class, students would learn about Ecology that had sub topics such as habitat, species, population, community and ecosystem. When he explained about living things in Ecosystems, he could not explain how the cycles of oxygen and carbon dioxide related to ecosystems? And what are the products and wastes that photosynthesis, cell respiration, and decomposition make? Sirod explained only plants could use photosynthesis process to produce oxygen for organism. He did not explain how two cycles of gases related to organisms like "most organisms took oxygen to release the energy in food. This process produces carbon dioxide as a waste product. The organisms release carbon dioxide back into the air"

Textbooks as Major Sources for Teacher's Subject Matter Knowledge

Sirod had the same understanding as Malai and Napaporn did. He taught science based on teaching manual books and textbooks. Sirod understood that he should teach science based on content indicated in curriculum. The teaching manual books and textbooks always referred to the NSCS; therefore, he could follow the content that presented in other teaching manual books and textbooks. Sirod expected that the students should understand science and know how to use scientific skills. Consequently, Sirod tried to cover every science topic for them in his instructional practice.

2. Sirod's Understanding and Practice about Pedagogical Knowledge

To present this section, Sirod's understanding and practice about pedagogical knowledge were interpreted into five sub topics of understanding and practice: knowledge of goals and purpose for teaching science; knowledge of instructional strategies for teaching science; knowledge of assessment in science; knowledge of learner and learning; and knowledge of curriculum, as the topics were presented in Malai and Napaporn's sections.

2.1 Understanding and Practice about Knowledge of Goal and Purpose of Teaching Science

Initially, Sirod Holds Constructivist Understanding and Positive Practice of the Goal and Purpose of Teaching Science

At the beginning of the CTM, Sirod was asked to clarify his understanding of what he expects his students to learn from his class. He showed that the students should learn science in aspect of understanding of science content, having science process skills, and applying science into daily life. Sirod also mentioned these three aspects were his goals for teaching science during the second central meeting (Sirod's Central Meeting#2: November, 2009). During the first interview, he commented that students should be able to know what the nature of science is and how scientists find science knowledge. His responses revealed some of his apparent understanding about the nature of science, science teaching and learning. Sirod held both constructivist and traditional positivist understanding about the nature of science. Sirod understood that scientific knowledge is tentative, focused on human creativity and imagination. As Sirod wrote in his written reflection:

> …Scientific knowledge can be changed if scientists find new evidence. Some science knowledge cannot be explained by experiment therefore scientists must have a good imagination and creativity to create new ideas. In addition, Sirod also presented his understanding in positivist side of the scientific method. The scientific method is a step-by-step process because many experiments need to begin with observation and follow by hypothesis formulating, doing experiment, getting results and making a conclusion.
>
> (Sirod's Written Reflection#1: July, 2009)

With regard to his understanding of articulating goals and purposes for teaching science the goals were not aligned with his practice. The results from classroom observations showed that Sirod taught mainly using lecture and experiment. Even though his lesson plans were focused on science content, science process skills, and science attitude, he still used knowledge transferring for students' learning of science. Sirod always presented information, generally through lecture or discussion, and questions directed to students were to hold them accountable for knowing the facts produced by science. At the start of most of his lessons, Sirod told his students what science concepts they would learn in this period. He wrote these science concepts on the blackboard and assigned the students to remember the concepts for answering the questions in Sirod's worksheet. On these worksheets, he included example questions from previous school examinations. Students were provided experiments to investigate after Sirod told the science concept to them. As a consequence, his teaching activities relied on a didactic orientation (Magnusson, Krajcik and Borko, 1999) which often involved delivering content to students in a lecture style format. Regarding to Sirod's class, it revealed that he had an obligation to uphold students' excellence for high education therefore, he needs to teach or support his students in ways that promotes students' abilities for school test and the National Standard Test. In central meeting, CTM team discussed how to set goals and purpose for teaching science after the CTM members were provided to study in the Science Curriculum Framework and the school-based science curriculum. Sirod expressed that he did not want to deliver only content knowledge to students but he expected that students could bring knowledge for improving their lives. As he stated "I would like students to pass examinations and could use knowledge with their daily lives such as students could find the solution when they engaged in issues pertaining to the impact of science on everyday life and make responsible decisions about how to address such issues" (Sirod's Central Meeting#1: July, 2009). His understanding of teaching expectation was not aligned with his practice as shown in classroom observation. There are many factors that affect Sirod in not being aware of encoraging students to apply science knowledge with their lives. From the many interviewed conducted during CTM I-II, the result revealed that Sirod was struggling with his science knowledge and when he taught he tried to focus only the sequence of science content therefore he did not have enough of time to motivate students' thinking in aspect of science technology and society.

2.2 Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science

Classroom Lesson Introduction: Teacher Introduces the Inquiry-based Lesson by Motivating Students' Interest and Clarifying the Main Question

Sirod was concerned with designing and organizing activities concerned with content. At the beginning of the CTM II, Sirod was asked to choose a unit of science to teach. He chose the concept of Ecology for 6th graders. From his written reflective, Sirod expressed that he struggled with how to sequence the learning activities related to science content. He commented that he would like his students to gain complete science content following the content that was identified in NSCS.

Similar to Malai and Napaporn, Sirod understood that he should motivate students' interest at the beginning of an inquiry-based lesson. As Sirod stated,

Researcher: Could you tell me what the science teacher should do for introducing an inquiry-based lesson?

Sirod: For my class, I used many activities for introducing my lessons. I sometimes provide student's real examples that they can touch and see or have them play games.

Researcher: What are the purposes of your activities?

Sirod: I would like to provide activities that can motivate students' interest and to have them know what they're going to study.

(Sirod's interview#1: July, 2009)

The lesson plan data supported Sirod's thought in that the teacher should introduce an inquiry-based lesson by motivating students' interest. In the first lesson plan, Sirod thought to stimulate students' curiosity using discussion about their survey data regarding what organisms were around their homes? In the second lesson, he planned to have students described the picture of ecosystem. In the third lesson, he showed students earthworms to observe what their roles were in the ecosystem. The last lesson, he showed students the picture of food chains and also had cartoons of animals that were in the food chain. The lesson plan data also reflected Sirod's conception in what he thought was important to link students' interest to scientifically oriented questions. Sirod planned to have students pose experimental questions in his four lessons.

With regard to Sirod's classroom instruction, the results showed that his teaching partly agreed with his understanding. In practice, Sirod introduced his inquiry-based lessons by motivating students' interest, clarifying the main question and/or providing the concepts of study. In the first lesson, he began the lesson through a motivational activity. Sirod had students write their data on a blackboard. The students and Sirod then discussed the words of habitat, organism, and adaptation. In the third lesson, Sirod started his lesson by providing students various ecosystem charts. The main question of this activity was “how did living thing and non-living things in the chart relate each other? In his last lesson, the teacher introduced his lesson by having students observe the diagram of food chains and provided them with cartoon animals. The students were assigned to create their own group of food chains. In his four lessons, Sirod explained the concepts before having students conduct investigations. After providing the concepts of study, Sirod informed the students of the question to investigate. However, the findings showed that Sirod did not elicit students’ prior knowledge in his three lessons. As evidence in his practice:

Sirod:	What data did you get from your observation? Could you write the data on a blackboard?
Students:	Students were writing their data on a blackboard.
Sirod:	How many habitats that you survey?
Students:	Three habitats
Sirod:	Are they different?
Students:	Yes, they are.
Sirod:	Do you think these habitats have same animals?
Students:	(Silent.)
Sirod:	Such as the first habitat is a tree located behind a house, what animal did you find on that tree?
Students:	We found birds, worm, insects, and ants.
Sirod:	The fish pond group did you see same animals like the tree group?
Students:	No, we did not. We found fish, frogs, and turtles.
Sirod:	Therefore, we can see that each kind of habitat has the needs of a different mix of organisms. A fish meet the needs of flogs, and turtles. The tree in behind a house meets the needs of birds and insects. Different kinds of organisms eat different foods. They live in different parts of a habitat. They interact with their environment in different ways. All of these are part of an

organism's role in its habitat. What is an organism's role that plays in this habitat?

Students: (Silent)

Sirod: It is niche.

(Sirod's classroom observation #1, January, 2009)

The above data showed that many questions Sirod used in discussions were yes-no questions and he asked about facts and definitions of science concepts. This kind of questioning may not engage students' participation in discussion because teacher concluded and told students the right answers. They needed to remember the definition of scientific terms. Some questions Sirod asked students and they could not answer because he did not give time for students to think about these questions. He not even gave 2-3 minutes to wait for students' answers.

Investigation: Students Should Be Provided Opportunity to Design and Conduct Investigations; However, in Practice Teachers Still Hold Main Role in Classroom

Sirod understood that students should be the person who posed the role of designing and conducting investigations. Sirod commented that he must direct the steps of investigation for students. As Sirod stated, "My activities were created to encourage students designing their own investigations first. I want students to design investigations and they then discuss with group members. But, from my experience students couldn't do it." (Sirod's interview#2: August, 2009). From the first card sorting, Sirod understood that investigations used in inquiry-based approach and were designed by following the steps of the scientific method. As Sirod explained, "Students can learn science through inquiry-based teaching and learning. They have to follow a process that covers the scientific method, which includes stating a problem, formulating a hypothesis, collecting data for testing the hypothesis, discussing data, and making a conclusion" (Sirod's interview#1: July, 2009). The lesson plan data also supported the result. In his lesson plans, Sirod developed the investigations by covering steps of the scientific method. He planned to have students review data from worksheets and conduct experiments after that students and teacher share their ideas to formulate conclusion. As he explained:

> …For my lesson plans, students were provided to do experiments. They also were engaged to search information by themselves through the textbook, the web, or interview from parents. As my students and I share our information and make conclusions, I try to show them how to formulate conclusions from our investigation such as information that came from many resources. I foster students to understand how to search for information and use it as a learning resource as well.
>
> (Sirod's Written Reflection #3: August, 2009)

In addition, Sirod's initial lesson plans presented that Sirod understood that assigning students to read about the concept of study before doing investigations was very important. With regard to Sirod's classroom teaching, the finding indicated that his practice partially agreed with his understanding. In his instruction, Sirod had students do experiments and read information from reading sheets. However, all of the investigations were designed by the teacher. In the first two lessons, the teacher told the students scientifically oriented questions that they would conduct investigations to find the answers. For the last two lessons, students addressed a scientifically oriented question by reviewing information from reading sheets and worksheets, as evidenced in an excerpt below.

Sirod: Did every group get the chart of ecosystem?

Students: Yes, we did.

Sirod: What did you see from the chart?

Students: There are trees, grass, small bushes, water fall, fox, rabbit, earthworm, and frog.

Sirod: Therefore, this activity we will explain how the populations in the chart interact with nonliving things in their environment. You can get some ideas from reading sheets before starting to

> do the activity. (Sirod's classroom observation #2, August, 2009)

The above data supported Sirod's understanding in that he understood that conducting investigation and reviewing information about an experiment from a learning resource was a sort of experiment. In the third and forth lessons, students did real experiments by following the steps of the scientific method. In practice, he provided students the opportunity to share ideas regarding investigational procedure. However, only some students communicated their thoughts.

Conclusion/Explanation: Students Should Be Responsible for Analyzing Data and Formulating Conclusions

Sirod understood that students should gain the opportunity to analyzed data and formulate conclusions. However, the teacher commented that in practice it was difficult for students to do without the teacher's guidance. His understanding agreed to his practice. In Sirod's class, he assisted students by discussing data and conclusions with them. As Sirod explained,

> ...My lesson plan, I want students to make conclusions. However, it takes a long time to finish my class. Sometimes students do not mention any concept that relates to science concept. I have to lead the students to discuss and formulate conclusions. We analyze data and answer questions (make conclusions) through whole class discussion. I conclude the result of experiments or investigations by having students write what we discuss in their reports.
>
> (Sirod's interview #4: September, 2009)

The lesson plan data also supported that students should be responsible for analyzing data and making conclusions. In his lesson plans, Sirod wanted students to analyze data and make conclusions. Students should learn to connect the conclusions with the science concept. However, he did not present that his teaching focused on linking the conclusions with students' prior knowledge. In the last lesson, students were assigned to write data and conclusions on worksheets. They did not share their data and conclusions with others. Students did not discuss together to reach a shared understanding of the conclusion. After concluding each investigation, Sirod did not connect the conclusions with science concepts and students' prior knowledge. He ended his lessons by concluding the result of the activity by having students write reports. Students were asked to hand their worksheets before going to study next subject.

Communication: Students Share Data and Conclusions with Others Lead by the Teacher

Sirod understood that students should be provided the opportunity to share their data and conclusions with other students. As he stated, "In my inquiry teaching, part of communication I have students present data and ideas regarding conclusions through discussion. Students were assigned to present their work in front of the classroom after that we formulated the main conclusion for the investigation" (Sirod's interview #1: July, 2009). The lesson plan data also supported his understanding that students should learn science by sharing data and conclusions. Sirod presented that he would like students to analyze data and make conclusions in his plans. With regard to Sirod's teaching practice, the result indicated that his practice was in agreement with his understanding. In his teaching, Sirod provided the opportunity for students to communicate their data and conclusions in the first two lessons. Students were randomly selective to present their data and conclusions. Although Sirod gave students chances to communicate their data and conclusions, there were only some students who joined the discussions. In some lessons, Sirod had students write data and conclusions on worksheets. When the students finished their investigations, Sirod concluded the result of activity and assigned students to write it down in worksheets. Students did not have a chance to communicate, justify, and evaluate their conclusions with alternative conclusions. The main role in the classroom was still with the teacher more than the students.

Group Work: Students Learn Science in Groups But Do Not Work Cooperatively

Sirod understood that students should learn science in groups. Group learning could enhance students to share their ideas and knowledge. To learn in groups, Sirod understood students should help each other and play their roles in completing the task as he stated “For me, group work is related with cooperative learning that is an approach to organizing classroom activities into academic and social learning experiences. Students must work in groups to complete the sets of tasks collectively. Everyone succeeds when the group succeeds” (Sirod’s Written Reflection#5: October, 2009). He also presented his understanding of students’ working as group in his card sorting that he wanted students to have more responsibility in their work. All students should be part of their group’s work. There should be 6-7 students per group because every group member could share their roles, not some students doing all the work (Sirod’s Card Sorting#1: July, 2009).

With regard to his practice, the result showed that Sirod only assigned students to sit as a group to incorporate group learning with passive teaching Even though each individual should have a specific duty such as head of group, secretary, recorder, and presenter. With regard to Sirod’s classroom instruction, the finding indicated that his practice was not compliant with his understanding. In practice, students sat in groups but they did not work cooperatively. In his four lessons, Sirod had students learn in groups. Students sat in groups of 7-8 members. However, in practice, many students did not play their roles and duties in groups. Around 2-3 group members of students did participate in learning activities.

2.3 Understanding and Practice about Knowledge of Science Curriculum

Science Curriculum Standard as Teaching and Learning Framework, Not School-Based Curriculum

In the CTM II, Sirod analyzed and then discussed the goals of teaching and learning science, learning standards, and learning stages in the National Education Act, 1999, Basic Education Curriculum, and Science Curriculum Framework with Malai and Napaporn. Sirod felt that everything in the documents he read was new to him. He was not familiar with technical terms such as "learning standard" and "strand" and so on. Therefore, analyzing and then discussing the issues in those documents lead him to develop an understanding of technical terms, educational goals, learning standards and teachers' roles. Even though Sirod felt he had learned from reading the curriculum documents, he felt that there was something he still did not understand. In the second central meeting of the CTM, the elementary science teachers including Sirod were asked by researcher how science curriculum was important for preparing teaching. As Sirod explained,

> …I study curriculum in detail to find out what topics in each unit that I need to teach and to cover complete science concepts. I use science curriculum standard provided by IPST more than school-based curriculum because I would like to make sure that my students learn and cover every science topic that is in the curriculum. Every time I prepare my lessons. I am based on what content that IPST curriculum says.
>
> (Sirod's Central Meeting 2# October, 2009)

From the first central meeting we discussed the National Education Act 1999, the Basic Education Curriculum, and the Science Curriculum Framework. Prior to the meeting discussion, Sirod thought that these were nothing new for him when he read the National Education Act. He commented that I understand what content I should teach the students, but still did not know how to bring this into a real classroom practice. His concern was similar to Malai's understanding.

Focusing More Likely on Intradisciplinary on Science Content Knowledge

Sirod understood that students should learn interconnect among science content as Malai's. He mentioned that students should not learn only an individual science concept. They should learn how to apply science knowledge into their daily lives. In terms of integration within science, Sirod mentioned that he would like to link among concept of characteristics of living things, animal and plant, behavior, and classifying organism into the concept of ecology.

However, his practice was not aligned with his understanding. Sirod did not connect any concept as he mentioned earlier to the concept of ecology. Sirod mentioned that he did not have good knowledge in science subject. When he prepared his lesson plans, he did same process as Malai and Napaporn did. His understanding of science content was based from many text books.

2.4 Understanding and Practice about Knowledge of Assessment in Science

Paper –and Pencil Tests as Major Assessments' Tools for Learner's Learning in Science Subject

Primilary, Sirod understood that students should learn science knowledge, practice science process skills, and have scientific attitude. In aspect of assessment for students' learning, he focused only on student conceptual knowledge as the learning outcomes. In his first two lesson plans about the Biotic and Abiotic, and Organism, Population, Community. He intended his students be able to recognize abiotic and biotic components of an ecosystem; identify interrelationships among the biotic and abiotic components of an ecosystem; acquire skills in estimating the population of an area; and appreciate the importance of food webs in conveying information about interrelationships in the local community. The result also agreed with his interview as evidence below:

Researcher:	What do you expect your students learn from your lessons?
Sirod:	I would like my students understand science concept, possess science process skills, and have scientific attitude.
Researcher:	Could you give me example of your teaching goals for the unit of ecology?
Sirod:	I would like my students inquire into the effects of change in an ecosystem. They can identify some events that cause change and examine an ecosystem that has experienced change. Students learn to appreciate the fragile nature of ecosystems. In addition, the students can explain how living organisms cooperatively share an environment.
Researcher:	What else's in the aspect of students' daily lives?
Sirod:	They can apply knowledge for improving their lives. The students can understand how human emotional, mental, spiritual, and physical needs are met within the ecosystem. They know the way to examine the impact of technological change on the local ecosystem.

(Sirod's Interview #4: September, 2009)

Even though these learning outcomes were specific, Sirod understood that paper tests could show how much the students learned and accomplished in Science subject. He did not assess students' learning covering his dimensions of goals and purpose for student learning such as science process skills, scientific attitudes, and attitudes towards science. With regard to his teaching, the result revealed that his practice did not agree with his understanding. In four lesson plans, Sirod employed broad assessment methods. Paper-and-pencil tests were utilized to assess the students' understanding of ecology's conception. He conducted these tests at the end of unit. After that he used the score as the result for student's learning. He mentioned that he collected every student's works and scores to grade student's outcomes. Sirod did not indicate any details of these methods such as when these methods were employed, and what concepts were assessed by these methods.

Worksheets as the Major Assessment Method for Knowing What Students Learn from the Classroom

Sirod recognized that assessment of learner's learning was important process that every teacher should think about. The classroom observations show that Sirod's major method of assessing was checking students' worksheets completed at the end of every class. Sirod returned these worksheets back to students in next class. He did not use any scale to evaluate student's learning. He just gave score of zero for not handing in a worksheet and 5 for handing in their worksheets. He stated that when he read students' worksheets, he would know about the student's learning. Students who would like to get average grade of 4 in science subject, only needed to hand in 80% of their work.

2.5 Understanding and Practice about Knowledge of Learner and Learning

Probing Students' Prior Knowledge Is Important for Enhancing a Student's Learning, However, the Teacher Does Not Implement Any Assessment for Understanding What Knowledge Students Bring into the Classroom

Initially, Sirod was rarely aware of students' prior conceptions. The first observing class, he taught students about the biotic and abiotic. Sirod did not consider the significance of the students' prior knowledge or their alternative conceptions in his teaching. His students were seldom involved in explaining and generating ways to test ideas. Even though Sirod engaged students' interest by asking students "In your own idea, what is biotic and abiotic?" students' responses to this question were not paid much attention too. For example, one of students answered that biotic should be animals in the forest. This answer seemed to suggest that students recalled scientific phrases from science textbooks rather than understand the concepts of living thing and non-living things. Sirod did not further probe what the students really meant by their answers. Additionally, it was found, from his responses in the card sorting, that Sirod held many alternative conceptions of the basic science concepts. For example, he was confused about characteristics of living things and non-living things, and organisms and species. In his answer about the organisms' basic needs, he explained for his concept understanding "All of animals or living things have basics needs. They need water and foods for growing. Different organisms want different basic needs" (Sirod's Card Sorting #1: July, 2009).

Sirod's lack of understanding of his students' prior knowledge was due to his incomplete understanding of science concepts. Sirod was confused about the concept of organisms, species, and habitats therefore he became concerned with ways of giving students content-specific feedback, rather than further probing their answers. He explicitly reflected that content in this lesson was interrelationships among the biotic and abiotic components of an ecosystem; when I was teaching this concept, it seems to be easier for me to tell students first what science vocabulary means (Sirod's Written Reflection# 3: August, 2009). On prior knowledge, Sirod presented his understanding about students' prior knowledge that directly affected learner learning. However, in his first two lesson plans, Sirod did not realize to elicit the student prior knowledge in teaching about the biotic and abiotic concept, and the concept of species, populations, and communities. Even though Sirod began his lesson by discussing units in students' daily lives (such as global warming, weather change), he rarely thought about what basic science concepts or prior concepts might be significant for learning the ecology concepts. In his third lesson, Sirod provided students worksheets and assigned students to do an activity. Students had to explain the meaning of science vocabulary. Sirod discussed why he did not explore students' prior knowledge because he was concerned about time constraints and knowledge in assessment that was also majors factors on Sirod's practice. All of his initial inquiry-based lesson plans did not have any parts that the teacher diagnosed students' prior knowledge and students' alternative conceptions.

The Role of the Student: Students Should Be Active and Minds-on Investigators; Whereas, in Practice Students Are Passive Investigators

Like Malai and Napaporn, in CTM I, Sirod already understood that the role of the student was that of an active and minds-on investigator. For Sirod, an active and minds-on investigator referred to those who did investigations with enthusiasm, shared ideas in discussions, posed experimental questions, formulated hypotheses, conducted experiments, analyzed data, made conclusions, and wrote reports. When the teacher conducted inquiry-based lesson, students should play the roles as active learner and minds-on investigator. As Sirod responded,

Researcher: What role of your students should they hold when you conduct inquiry-based lesson plans?

Sirod: In my opinion, students should play a role of enthusiasm. They should be curious about things they study. I try to motivate their curiosity by using students 'interest. They must seek the answer of things they want to know. They might do experiments or search for information. It's dependent on the concept. Sometime the teacher has to be leader as well.

(Sirod's interview#3: August, 2009)

The lesson plan data suggested that Sirod thought students should also share ideas in discussions, pose experimental questions (scientifically oriented questions), formulate hypotheses, conduct experiments, analyze data, make conclusions, and write reports. With regard to Sirod's classroom practice, the finding indicated that his practice was not in agreement with his understanding. In Sirod's teaching, students were passive investigators. They occasionally shared ideas in discussions. In the four lessons, Sirod provided opportunities for students to raise scientifically oriented questions, formulate hypotheses, design investigations, analyze data and formulated conclusion. However, only some students shared their thoughts. The majority of students waited for the teacher to answer his questions. The role of as the students was passive investigators.

The Role of the Teacher: Teacher Should Be a Guider, Facilitator, and Motivator; However in Practice the Teacher Plays Mainly Roles of Lecturer

In CTM I Sirod understood the teacher role as guide and facilitator. Sirod's conception of the teacher role was broadened. He accepted that the role of the teacher was guide, facilitator, and motivator. After Sirod attended the first central meeting, Sirod's response from the interview showed that his understanding about the role of the teacher was consistent with teaching and learning based on constructivism. He understood that the inquiry-based teaching and learning, the teacher should play as guide and facilitator. Sirod did not understood the teacher as an activity director way. This result also was agreed by the data from group discussion that reflected on Sirod understanding of the teacher's role. The teacher should not be an activity director and that students should assume this role. As he stated:

> …In my lesson plans, my role was a facilitator. Students are active learners. I helped them when they had a problem or did not understanding about investigations. I had to tell them what they should do. In fact, I think students should be the leaders [of the learning activity] and I should only be an assistant. Students should think and take action on the learning activities. I should assist students in everything they need such as motivating their interest, guiding them how to design the survey, doing the activity, and preparing learning materials for them (Sirod's Central Meeting #1: July, 2009).

With regard to Sirod's instructional teaching, the result was not aligned to his understanding. In his lesson of the CTM II, Sirod motivated students' interest and posed scientifically oriented questions. He diminished his role as an activity director. Sirod asked students to design the investigation, make decisions about the data they wanted to collect, and develop a method suitable for collecting and presenting their data. He guided students how to design the investigation and choose data collection method as well as the presentation format. The last two lesson plans he assigned students to conduct investigations following his worksheets. In the classroom, Sirod designed the learning activities, motivated students' interest, posed questions, guided students how to do the activities, and prepared learning materials for them. In his reflection, Sirod simply wrote, "My roles are an activity director and assistant" (Sirod's reflection #4: November, 2008).

The findings of Sirod's teaching practice during CTM I, presented that there was an inconsistency between his understanding and practice. His understanding of teacher's role for inquiry-based teaching and learning based on constructivism were multiple roles in his lessons (activity director, motivator, guide, facilitator, and lecturer). These roles were different when he implemented them in his class.

3. Sirod's Understanding and Practice about Knowledge of Context

Consistent to Malai's and Napaporn's understanding of the importance of context for teaching and learning science. Sirod understood that science in the elementary school was framed by the social and cultural context of elementary schooling. This varies considerably from school to school. Sirod indicated that understanding the context of schooling is an essential starting point for making sense to develop teaching practice systematically. He mentioned that students 'experiences fostered by family, local community, and society for each student that influenced that student's learning of each science concept. A science teacher should understand about the community, school, and students' background. Students' backgrounds were different and their abilities to learn science varied. As he mentioned:

> …I understand while coming from a low socio-economic background is not necessarily predictive of success or failure for individual students, the achievement levels for this sub-group as a whole within our schools are cause for great concern. These factors indicate that schools with students from low socio-economic backgrounds require additional support to achieve the same outcomes for them as for other groups of students. Therefore, the teachers

should know about their student's background and can prepare lesson according their abilities.

(Sirod's Central Meeting #2: November, 2009)

With regard to Sirod's practice, the result presented that his practice was compliant with his understanding in the aspect of providing and preparing learning material for students who did not have good financial support. In addition, Sirod then explained more about his understanding on the aspect of context. He thought that socio-economic disadvantage was generally associated with factors such as low-quality living environments, mobility, family unemployment or underemployment, lack of access to resources that stimulate learning such as books and pre-school programs, poor health and social discrimination. These circumstances equate with poor attendance, lower retention rates, less readiness for schooling. Sirod also showed his ideas with community. He said "I used to bring students to the market for studying concepts of technology and environment. Students were more interested in studying when they can interact with real things. The students can see real problems about pollutants that affect their own environment in the students' local community. Various teaching strategies are needed for science teachers but knowing about your students in aspect of students' differences of interest and abilities are also the teachers' requirements (Sirod's Interview 4# September, 2009).

In Sirod's' instructional practice, he realized that teaching and learning science related to contexts of community, school, and students were crucial to teaching success, he did use school and community resources such as the garden, computer room , and market for enhancing students 'learning science. Many aspects of Sirod's understanding on contextual knowledge seemed to be that he understood how to integrate contexts of district, community, school, and students into his lessons. Many times Sirod implied that science teaching can be meaningful in coping with the demands of diverse learning populations if teachers make an effort to become knowledgeable about their own teaching context.

Sirod's Understanding and Practice of PCK After Participating in PCK-based CTM

In this section, the results are discussed in terms of Sirod's PCK development through the activities in CTM. He had participated in the CTM from July 2009 until March 2010. The CTM was a long-term professional development. There were four stages of CTM (CTM I- CTM IV). For the second semester, Sirod taught in unit of Electricity and Magnetism. He used the topic of Electricity to develop his lesson plans. These topics were Statistic and Current Electricity, Conductors and Insulator, Electric Circuits. He started to prepare his lesson plan with his CTM members from November, 2009 after he participated in CTM II. Like Malai and Napaporn, Sirod implemented the lessons by following the 5 Es inquiry process (DCIC and IPST, 2002). This process is same Malai's and Napaporn's 5E. The 5E inquiry process consists of five steps: engagement, exploration, explanation, elaboration, and evaluation. Sirod's subsequence understanding of Pedagogical Content Knowledge [PCK] was interpreted by various sources of data. Classroom observations, interviews (Individual interviews and card sorting), reflective journals, inquiry-based lesson plans, and central meetings. The development of knowledge bases is presented by considering aspects of PCK; understanding and practice of subject matter, understanding and practice of pedagogical knowledge, and understanding and practice of knowledge of context.

1. Sirod's Understanding and Practice about Knowledge of Subject Matter

Before attending the CTM III, Sirod was provided a chance to express what science unit or topics that he was not confident in teaching. In the second central meeting, he chose unit of Electricity and Magnetism for using in CTM. What had changed Sirod's understanding and practice about knowledge of subject matter? This question took almost one year to answer. In the time Sirod was in CTM, he showed the CTM team that he had changed his practice consistent with constructivism. Finally, the CTM team could see his progress in his instructional practice.

Understanding Science Concepts of Electricity through Sharing and Discussing with CTM Team

At the second central meeting, Sirod told CTM members about his struggle in teaching of concepts of Electricity and Magnetism. These sentences were noted at the second meeting and also were in his reflective journal. In developing of lesson plans, Sirod listed concepts of Electricity that students should gain from his class. He brought these concepts to discuss with CTM members. The first lesson that he co-taught with the researcher was the Static and Current Electricity; he prepared content framework to discuss with CTM team. He started to explain that students should have same understanding about how electricity occurs when there is an imbalance of charged particles. As he mentioned to CTM members:

> …To understand what electricity is, we have to look at atoms. Students should have basic understanding of atoms that they are the tiny building blocks that make up everything around them, from the air we breathe to the clothes we wear. Everything is made of atoms. Each atom contains small particles that have an electric charge. Some particles have a negative charge (-). These particles are called electrons. Other particles have a positive charge (+). They are called protons. Since everything is made of atoms, everything contains charges particles (Sirod's Central Meeting # 2: October, 2009).

He went to the library to study by himself and then he wrote into his journal the parts of science content that he was confused about. Sirod would first; consult with his co-teachers about these parts of science content; he then would bring it into CTM central meeting to share the knowledge with the other members. In Sirod's lesson plans, it showed that Sirod's concepts of Electricity were consistent with Sirod's' instructional practice, he taught students systematically. Students were asked to connect between concepts during Sirod's conversation to his students in class. Students learned basic concepts in the first lesson that was about Charged Particles; atoms are made up of electrons, protons, and neutrons. Neutrons have no charge. Electrons have a negative charge. Protons have a positive charge. Electricity is a form of energy that is produced when electrons move from one place to another place. I would like the students realize what makes the electrons move is the charges that different particles have. (Sirod's Central Meeting #3: December, 2009).

With regards to Sirod's practice, he asked many questions to his class of students. These questions encouraged students to think about conceptual linking. Data from classroom observations, reflecting journals, and inquiry-based lesson plans reflected that Sirod understood concepts of Electricity. He had improperly prepared the science content. Some topics of Electricity that he did not understand were brought to discuss with the CTM team, for example, topics of static and current electricity and series and parallel circuits. For the topic of series and parallel circuits, Napaporn had attended a workshop and she had various teaching media therefore, she also shared her teaching ideas and media to Sirod and Malai. In February, Sirod was interviewed by card sorting. He picked a card that taught students that electricity is a form of energy that is made when electrons move from one place to another place. In addition he suggested that he would like to enhance students to learn "Atoms are made up of electrons, protons, and neutrons. Like charges repel, or push against, each other. Electrons repel other electrons, but they are attracted to protons. Protons repel other protons, but they are attracted to electrons. Those forces of attraction and repulsion make electrons move away from areas with a negative charge and toward areas with a positive charge. This movement is electricity" (Sirod's Card Sorting# 3: December, 2009). Sirod presented that he improved his knowledge about Electricity by discussing with CTM members. As Sirod reflected "I gained more understanding about what electricity is and how it happens during discussion of CTM meeting. Before I did not know how electricity traveled through wire? For four lessons, I teach students comfortably and feel relaxed. I understand what purposes of my teaching activities and how these activities connect to science knowledge (Sirod's Reflective Journal #13: December, 2009).

Being Confident Teaching in Concept of Electricity and Understanding How to Link Each Concept in Topic of Electricity and Magnetism

After Sirod participated in CTM as one co-teacher, his confidence levels in explanation of science content were different from the past. As data from Sirod's card sorting interview, he selected a card that had a teacher who taught concepts of electric circuits with the concept "an electric circuit is a pathway that electrons flow through. The students were taught by lecturing. With regarding Sirod's understanding of science knowledge, he mentioned that he would change the teaching strategy for this concept. Students were provided a flashlight to study were asked to explain how it worked? Students and I would discuss to get the concept "Electric circuits allow electrical energy to be changed into other forms of energy such as light from the flashlight. Parts of a circuit must have a source of push for the electrons. That means the circuit must include a battery or an electrical outlet. It also has a device that it operates, such as a light bulb or a radio. A circuit usually has one or more switches. A switch starts and stops the flow of electrons through the circuit" (Sirod's Interview#7: December, 2009).

With regard to Sirod's Practice, he and his co-teacher (Napaporn) taught about electric circuit together. Sirod provided students with a light bulb, battery, and wire. Students were challenged to design how make the light bulb work. After that he gave a switch to each group and asked students what role of the switch is? Students, Sirod, and his co-teachers continued the class like they were in an active meeting and the students acted as active listeners, questioners, and speakers.

2. Sirod's Understanding and Practice about Knowledge of Pedagogical Knowledge

The CTM designed by the researcher and this CTM was based on teachers' data collected before they participated in CTM. The data involved developing understanding and practice of PCK. CTM was not short-term PD. A total of 32 weeks that Sirod was involved in PCK based CTM. Sirod had to spend time together with other CTM members sharing, reflecting, discussing, planning, teaching, and evaluating. The following paragraphs explain what Sirod's progress on his understanding and practice about pedagogical knowledge during and after he engaged to CTM II-IV. These were five aspects of knowledge presenting Sirod’s changes in pedagogical knowledge.

2.1 Understanding and Practice about Knowledge of Goals and Purposes for Teaching Science

Before Sirod was involved in CTM, he had some traditional practices that emerged in Sirod’s classroom observation. He taught students by knowledge transmission that a teacher corrected students’ alternative conceptions by telling and explanation. Consistent to Sirod’s initial understanding and practice about articulating goals and purposes for teaching science were focused on content knowledge as the central goals. In CTM II: preparation and CTM III: Co-planning, Sirod‘s changed his understanding of goals for teaching science gradually from the beginning of CTM I until last day of PD program. His changing of goals and purposes for teaching science were categorized into two aspects as follows:

Articulating Goals and Purposes for Teaching Science in Aspects of Science Content, Scientific Process, Scientific Attitude, and Attitude toward Science

In CTM I, learning outcomes of Sirod’s lesson plans were focused only on students’ learning in science content and science process skills Similar to Malai and Napaporn. Sirod’s initial practice always used didactic way. Transmitting the facts of science was often the teaching strategy in Sirod’s class. Since week 12 of CTM, Sirod adjusted his understanding and practice about articulating learning outcomes in Science subject covering three domains. In CTM IV: co-teaching and evaluating stages, Sirod explained how he taught students with the topic of Conductors and Insulators. Students worked together in groups. He provided them parts of a circuit and asked them to design how to connect wire that makes a light bulb work. After that he let students try to use solid test items (glass rod, piece of silk, piece of wood, coin) and liquid test items (tap water, lemon juice, salt water solution) as one component of circuit. With regard to Sirod’s practice, the result agreed with his understanding. Sirod facilitated students to define investigative questions. The students designed their own electric circuit. They investigated and recorded data to formulate conclusions. Students were provided parts of a circuit and they used those parts to learn the concept of open-closed circuit and conductors and insulators. Sirod opened time for students' presentations. Students were encouraged to discuss the lesson. In Sirod's practice, students were fostered to gain scientific knowledge as active learners, to use scientific skills in investigating, and to apply scientific knowledge to solve local problems.

Initially, Sirod understood that teaching science through inquiry he should emphasize learning science content knowledge and science process skills. After CTM progressed, he extended his understanding regarding the instructional objective. Sirod recognized that the aims of science teaching and learning included not only scientific knowledge and process skills, but also scientific attitudes. The data from his lesson plans of the CTM III and the CTM IV showed that Sirod focused his inquiry-based lessons on scientific knowledge, science process skills, and scientific attitudes compliant with the NSCS like Malai did. With regard to scientific attitude, Sirod wanted students to realize the importance of electricity and how to produce it. Students were encouraged to connect knowledge to terms of environment and local community. As evidence below;

> …Students can work as a judge to recognize the problems. After the students was learning science. Students were encouraged to have understanding of learning content, skilled scientific processes and a good attitude to science.
>
> (Sirod's Card Sorting#4: February, 20010)

In Sirod's class, students were asked to answer "What's going on? Without warning, the lights go out, your computer shuts down, your music stops, and your clock goes blank. No electricity, where are the candles?" Sirod would like students know how important electricity is to students' lives. Therefore, they would learn to use and save the electricity.

The research findings suggested that Sirod's practice agreed with his understanding. Through the learning activities, students had the chance to practice several skills including observation, measurement, using numbers, data organization, and communication. To address the goal of teaching scientific attitudes, Sirod assigned students to work with others in small groups (5-6 students). Students were engaged to learn as a group collaboratively.

Teaching Students Nature of Science as Teaching Goals

As the CTM progressed, Sirod's understanding and practices about setting goals and purposes for teaching science that student should learn and start to integrate the nature of science as knowledge, not only science content. Sirod explained the nature of science shifted to be more constructivists, specifically, about the nature of scientific knowledge. During the CTM, Sirod was provided with many opportunities to express his initial understandings and compare these understandings to constructivist understandings of the teaching and learning of science. For example, in 15th week, he was asked to analyze and discuss goals of teaching and learning science proposed in the Basic Education Curriculum, and the Science Curriculum Framework. At that time, like Malai, Sirod realized that the nature of science was important in aspects of teaching goals and leaning outcome. According to his responses in the subsequence understanding and practices in a real classroom, it was found that Sirod's understanding and practices about scientific methods were more on constructivist in nature. He noted that there were many methods for obtaining scientific knowledge and students should learn scientific methods that did not need to be a series of making observations, formulating hypothesis, doing experiments, and concluding about results.

Additionally, Sirod's understanding about teaching and learning science by learner- centered on constructivist understandings were unchanged, but broadened in terms of pedagogical knowledge. Contradictory, Sirod's teaching was changed gradually especially when he co-taught with Napaporn (Grade 5 teacher). As Sirod stated "I always thought that scientific knowledge cannot change forever because scientists spend long time to formulate theory and law. After I co-planned, taught, and evaluated with Napaporn, she showed me many documents that were useful for teaching science and I understood nature of science clearly because of her. (Sirod's Interview#9: January, 2010).

The data from lesson plans and classroom observations during the four stages showed that Sirod had more understanding to connect what he already knew from his experience to what he learned from CTM. His instructional practices were aligned with his understanding. Sirod's articulating of learning outcomes covered the three aspects, scientific knowledge, scientific process skills, and scientific attitudes. He had changed his understanding and practice gradually since CTM progressing.

2.2 Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science

Classroom Lesson Introduction: Teacher Begins an Inquiry-Based Lesson by Motivating Students' Curiosity and Clarifying the Main Question

In the CTM I, Sirod understood that he should introduce an inquiry-based lesson by motivating students' interest and clarifying the main question. After he participated in the CTM, Sirod still held the same understanding regarding classroom lesson introduction. Unlike Malai and Napaporn, Sirod did not recognize that he should also elicit students' prior knowledge. After Sirod experienced the CTM, the findings indicated that Sirod did not gain new understanding regarding the classroom lesson introduction in inquiry-based teaching and learning at the beginning of CTM. During the third meeting of the CTM, the data indicated that Sirod realized he did not plan his inquiry-based lesson by following the essential features of inquiry-based teaching and learning, as evidenced in an excerpt below.

> …After I talked with CTM team they thought that I should revise this lesson. There were many concepts that I do not connect to learning activates. By sharing, reflecting and discussing about our lesson plans, I also realized that my lesson did not represent the inquiry process. I use many activities to engage students but most of the activities were leaded by me. Students were provided to investigate following instruction. After I discussed and shared my lesson plans to CTM members, I have some ideas for improving my lesson plans such as teaching goals and activities should be related.
>
> (Sirod's Central Meeting #3: December, 2009)

After the third meeting, the findings revealed that Sirod began to recognize that to teach science through inquiry he should begin the lesson by motivating students' interest and making it clear for students the questions he wanted them to address, as evidenced in his lesson plan. The data from the group discussion during the third meeting reflected that Sirod understood that he should begin the inquiry process by motivating students' interest, as evidenced previously in the section of the teacher role. The data from his lesson plan of the CTM III reflected that Sirod maintained his initial understanding in that he should motivate students' interest and have a central question to investigate. In his lesson plans in the CTM III, Sirod planned to motivate students' interest by using pictures of lightning and discussions. After that, he asked students questions including: have you ever seen a spectacular display of lightning, like the one in this photo? Why do people who get hit by lightning die? Is electricity the same as the electricity that runs appliances and makes life so convenient? However, these questions did not require scientific responses. Students used only their opinions to address the questions.

With regard to Sirod's teaching practice before participating in the CTM, the findings showed that there was consistency between his understanding and practice. For instance, in the lesson of the CTM IV, after the motivational activity, Sirod posed a scientifically oriented question. He then asked students to predict the answer, as shown in an excerpt below.

Sirod: Have you ever seen a spectacular display of lightning, like the one in this photo?

Students: Yes, I saw it last week when we had big rain.

Sirod: What did you see?

Students: I saw big lightning that was bright and had loud sound.

Sirod: If you live in one of the drier parts of Thailand, you've probably seen and heard. Even if you have never seen lightning, it is occurring somewhere in Earth about 100 times. Can the lightning kill human or animal?

Students: Yes, it can. I saw from movie.

Sirod: How it can kill people?

Students: Burn people by high volt electricity.

Sirod: Is that electricity the same as the electricity that run a CD player? Let's find out what type of electricity of lightning is. Please read activity 1 on the worksheet: Static Electricity and Current electricity. There are materials for the activity: balloons, pieces of paper, bamboo stick. Inflate a balloon, and put it against a wall. Watch what happens when you let the balloon go. Rub the same balloon with a wool cloth or your hair for a few seconds. Then put it against the wall. Observe what happens. What questions do you think we use for this investigation?

Students: What happen to the balloon the first time?

Sirod: What else?

Students: What happen to the balloon the second time? How long does the balloon stay on the wall?

(Sirod's classroom observation #5: January, 2009)

During the first central meeting, Sirod compared teaching strategies of the CTM. Initially, he commented that his teaching was teacher-centered because he gave many assignments to the students. At the beginning, he thought that his classroom was student-centered. Sirod became frustrated in his thinking about teaching strategies. Until CTM III: preparation stage, he was clear in his ideas. Through the preparation and co-planning stages in Weeks 13 to 20, Sirod had learned about constructivist-based teaching strategies especially, inquiry approach. Generally, he felt that after participating in the CTM activities he better understood pedagogical sequences that might be used in constructivist-based teaching strategies. He had learned how to introduce and conclude a lesson, and how to connect learning activities in science lessons. As he discussed with other CTM members in the forth central meeting,

Sirod's development of pedagogical knowledge was presented in his classroom, he focused more on student thinking and their interests were important criteria of student- centered teaching. He thought that the lesson introduction should aim to elicit students' prior knowledge, and guide teachers in the next step of teaching. Teachers should ask questions that students were able to answer. The data from interview and written reflective showed that not only asking students questions, in some classes Sirod also introduced his class by showing real specimens, telling stories, and providing interesting news to students. With regard to Sirod's instructional practices, he started his classes with scientifically oriented questions and the questions were based on students' interest, curiosity, and prior knowledge.

Investigation: Hands-on and Minds-on Are Integrated into Teaching Activities

To increase students' success in learning science, Sirod's inquiry lesson plans were based on the 5Es and in the stage of exploration, students' investigation for answering authentic questions that were generated from student experiences was the central strategy. For example, in the lesson about Static and Current Circuits, all the groups were provided opportunity to have Hand-on experience by surveying and collecting data from investigation. Sirod's teaching was different from the first semester. Before students always conducted experiments following teacher's procedures. Therefore, his teaching was active directing until week 15 of CTM II: preparation stage, Sirod's constructivist understanding was consistently presented in his reflective journals during CTM II.

Moreover, Sirod's lesson plans were focused on Hand-on and Mind-on activities. Students conducted their own investigations. These lessons were about Electricity. They got opportunities to design and manage their data in their own way. As Sirod's teaching:

Sirod: What did we get from the first activity?

Students: The balloon did not stick on the wall when you held a balloon against a wall. For the second time, a balloon was rubbed by a wool cloth; it was stick on the wall.

Sirod: Why did it happen like that? After you discussed with your group members, what did your group think?

Students: Because the balloon changed charges.

Sirod: What kind of charge change?

Students: Electrons and Protons

Sirod: Did any group try to pick up small pieces of papers by the rubbed balloon?

Students: Yes, we did. The rubbed balloon can pick up small pieces of paper.

Sirod: I have a reading sheet for you. Please read it and connect to your investigation. Why the balloon can stick on the wall and can pick up some papers.

(10 minutes for student's discussion in group)

Sirod: O.K. Does anyone have an answer to explain to the investigation?

Students: We found that when we rubbed a balloon with a wool cloth together, both objects become charged.

Sirod: How do they charge?

Students: The rubbing moves the charges from their normal places. The rubbing knocks some electrons off the wool cloth, causing the cloth to change from being neutral to being positively charged. The balloon picks up the electrons and change from being neutral to being negatively charged.

Sirod: How did we know which charge they hold if we rub two balloons?

Students: We rub two balloons and put close together. If they have same charges, they will push away.

Sirod: Does any group have different ideas of investigation?

Students: Our group use stick. We inflate two balloons. Tie each balloon with a string. Hang the two balloons close together from a meter stick or pole. Rubbing both balloons and observing what happen.

Sirod: How does it different from rubbing only one balloon?

Students: We should rub one of the balloons with a wool cloth and then observe what happens. Second time we rub both balloons.

(Sirod's Classroom Observation#5: January, 2010)

Not only the first two lessons that Sirod provided students very interesting activates, the third and fourth lessons also had very interesting activities for students to learn science such as building electric circuit using lemon as power source. Students were provided chances to design their own investigations when Sirod co-taught with Malai. In addition, every group got time to present their data from the experiment they designed. Students, co-teacher, and Sirod then discussed the data and made conclusions that related to scientific concepts. At the end of lesson, Sirod assigned students to create mind mapping that concluded what they learned? In Sirod's worksheets, there were open questions and they were about linking science knowledge into development of local community and how to maintain the environment in society.

With regard to Sirod's instructional practices, after students, Napaporn (Co-teacher), and Sirod finished their discussion and got the central question that they would like to find an answer too. Students were given time to formulate their hypothesis by working in groups. The groups designed their investigation and data recording. Sirod better understood and practiced attributes of student-centered learning. Hands-on and Mind-on activities were significant criteria of student-centered teaching. Related to data from central meeting, Sirod discussed with CTM members and he shared his ideas of teaching and learning science through inquiry. Students should be led to make their own investigations and to draw upon their own inferences. They should be told as little as possible. Articulating hypothesis, planning, investigating, recording, discussing, and formulating conclusions were major scientific process skills that Sirod would like his students to get from his teaching. Sirod's instructional practices were aligned to his understanding of Hand-on activity.

With regard to Sirod's teaching practice before and after the professional development experience, the finding revealed that he could integrate what knowledge he learned from CTM team to his practice. When Sirod attended CTM, sharing, reflecting, and discussing with others, helped him to adjust his understanding and practice of pedagogical knowledge related to reformed education and based on Constructivism. In Sirod's instructional class, students were provided time to think about how to design investigation; what is hypothesis; how to record the data; and what conclusions related to the data. Sirod gave students opportunities to learn science through Hand-on activities or investigations. Additionally, students were encouraged to link their experiences with the conclusions by creating mind mapping. Mind-on activity also was referred in this time as well

Conclusion/ Explanation: Active Students Are Provided to Analyze Data and Formulate a Conclusion

Similar with Malai and Napaporn, in CTM I, Sirod understood that students should be responsible for analyzing data and formulating conclusions. However, Sirod did not know that he should link the conclusions to students' prior knowledge. After participating in the CTM, Sirod maintained his initial understanding that students were the ones who analyzed data and made conclusions. However, his understanding regarding prior knowledge was changed. Sirod began to conceive that he should link the new knowledge with students' prior knowledge.

As CTM progressed, Sirod still perceived that students were the ones who analyzed data and formulated conclusions. He wanted students to share their knowledge that they had learned from the last unit through discussion. In addition, in his practice, Sirod purposed to connect the conclusion with student's prior knowledge. After experiencing the CTM II-IV, Sirod held the same understanding that students were the ones who analyzed data and made conclusions. It seemed like Sirod began to understand the notion of linking new knowledge with prior knowledge, as he mentioned during the second meeting "My teaching and learning activates also focus to elicit students' prior knowledge while the observation in the activity aims to have students learn the concept. After that, we have students compare between what they initially understood with the knowledge they learned from the observation. So, if we cut the first activity, it means we don't have any information about the students' prior knowledge (Sirod's Central Meeting #2: November, 2009). His response during the second interview showed that Sirod understood students were the ones who analyzed data and made conclusions. As Sirod stated, "I think students were those who analyzed data. I helped them by asking and leading our discussions. The questions used in discussions guided them to make conclusions." (Sirod's interview #3: January, 2009). The data from lesson plan supported that Sirod planned to have students present their data. He then planned to discuss the data with students in order to guide them to analyze the data and formulate conclusions. After that, Sirod planned to connect the conclusions with related science concepts as well as students' prior knowledge.

With regard to Sirod's teaching practice, the results indicated that the teacher's teaching practice in CTM I did not agree with his understanding. Sirod thought he should be the one who analyzed data and formulated conclusions. However, in practice, he and students analyzed data and made conclusions together in four lessons. After the CTM progressed from CTM II- CTM IV, Sirod's teaching practice was aligned with his lesson plans. Sirod and students analyzed data together in one lesson. Sirod's prior understanding was students should analyze and formulate conclusions independently. After professional experience, Sirod added his comments on students, the teacher, or both parties should analyze data gathered from an investigation. Students formulated a conclusion/explanation from evidence and their prior knowledge to address the scientifically oriented question. In addition, students, the teacher, or both parties should connect the conclusion/explanation to scientific knowledge.

Regarding to Sirod's teaching class, he concluded a lesson and organized student scientific conceptions. Students participated in discussion and helped him draw conclusions about what they have learned. Sirod blended his teaching from teacher to student-centered style. After experiencing the preparation stage of CTM, the data lesson plans, classroom observations, and individual interview showed that Sirod's teaching could help students to formulate conclusions and Sirod's instructional classes focused to connect the conclusion to students' prior knowledge. Finally, students were engaged to link the conclusion to scientific concepts as well, as the following evidence was illustrated in below.

Researcher: In your class, after students finished their investigations. Who analyzed data and made conclusion?

Sirod: Students were provided time to make their own conclusions in the first group. The students' then shared and discussed in class. My co-teacher wrote these conclusions on the blackboard and I then used aspects that were similar and clustered that into the central conclusion.

Researcher: How do you help students analyze data and make conclusions?

Sirod: Asking questions. I asked students to write their own data on flip board paper and they discussed in their own group to formulate a groups' conclusion first. After that they presented their own conclusions to the other groups. We discussed the conclusions together. For our discussion, students were encouraged to see what differences were among their conclusions? (Sirod's Individual Interview# 8: January, 2010)

Communication: Students Share Their Data and Conclusions with Others.

Prior, Sirod's understanding was science teachers should provide opportunity for students to share and discuss data. His understanding was contradictory to Sirod's teaching practice. In his initial classroom, he only assigned one or two group to present their data. After Sirod had professional experience, he created lesson plans focused on students' presenting, discussing, and evaluating. Sirod still maintained his understanding of students' communication from prior study. Sirod's' response during interviews in the CTM II: preparation stage.

Researcher: What do you understand about students' communication?

Sirod: Student's presentation is the best way that they can communicate with each other. They then have a discussion about that data.

Researcher: What was your role during student's presentation?

Sirod: Questioner and Helper.

Researcher: After you attended CTM, we had a chance to discuss this topic. What you would like to adjust in your teaching for the next semester?

Sirod: I still would like my students to have the opportunity to show what they concluded from investigations or experiments. Students should reflect on other groups' data and conclusion. I think that there are many ways to promote students' communications. My initial understanding and practice, I understood that providing time for students to present their data was communication.

(Sirod's Individual Interview# 5: November, 2009)

In Sirod's first lesson, he co-taught with Napaporn on the topic of structures and functions of Electricity. Sirod illustrated that he added more activities for students to present their data and conclusion. From Sirod's interview (Previous example) was consistent to Sirod's teaching practice. He provided 5 minutes for each group to present their data and conclusions. Sirod used questioning method to encourage other students to express their ideas on students' presentations as evidence below. The second co-teaching of Sirod, he showed that his understanding of providing students opportunity to share, reflect of teaching to student-centered way was gradually developing. Students communicated and justified their conclusion/explanation with other students. As Sirod's reflective journal from this class, he mentioned that his co-teacher helped him to sequence teaching processes and classroom management.

In Sirod's microteaching activity of the conception of Electricity, his teaching was more in line with constructivist understandings of learning. The learning activities focused on student conceptions and learning. For example, prior to teaching the Electricity concept, he explored student's prior knowledge about the concept of atom, and charge by distributing worksheets to students and asking questions. After the students completed the worksheet, Sirod and his students discussed the questions in the worksheet together.

In summary, Sirod developed his knowledge of teaching strategies. He added to his understanding of student-centered learning by providing students the freedom to learn what they wanted, more thought about student prior knowledge, and about hands-on and Mind-on activities as key aspects of student-centered teaching. The sharing, reflecting, discussing and evaluating on teaching were significant activities contributing to Sirod's knowledge of teaching strategies. Sirod's decision regarding the design of lesson plan seemed to be impacted by his constraint regarding time.

Group Work: Students Learn and Do Science in Group

After experiencing the CTM II: preparation, Sirod began to understand the significance of students' learning as a group. Consequently, he consulted this concern to other CTM members. Sirod agreed with Napaporn that social interaction that the best way for students' to learn how to interact with others. Sirod provided learning activities that promoted students to work as a group. The following evidence is discussion among CTM members during the second central meeting.

Sirod: I had students learn in groups. Each group had 5-6 members. Individual members had a specific role and duty. I guided them at the beginning of the semester about their roles and duties. Students were grouped according to their number. So, they were randomly clustered into groups. I mix their abilities and genders.

Malai: I always provided students to learn as a group. They were clustered randomly. Sometime I gave them candy. Students who got same style of candy stay in the same group. In this case, I want students to work with a new group's members. They would learn and share their experiences.

(Central meeting #4: January, 2010)

Sirod's conversation during the second central meeting also showed that he recognized that students' interaction with the activity was decreased when there were too many students in a group. He realized that promoting students to have social behavior could happen in the classroom starting from teaching the students how they work as a group. Teachers should engage students to participate in task-oriented learning and help the students move to relationship-oriented learning. Therefore, students were asked to organize their own roles in the group. Sirod reflected that when students had their own roles, they could work collaboratively.

With regard to Sirod's practices of four lessons, the result presented that students in Sirod class were clustered into groups and there were 5-6 persons per group. Each group consisted of mixed genders and abilities. Students were grouped by picking a ping-pong ball. Every member in group had his/her roles. They had their own reasonability for the group. In the first lesson, Sirod assigned students to work as a group for learning the concept of Electricity. The third lesson, he used learning stations. Students were provided activities that related to open-closed circuits and series and parallel circuits. Therefore, he did not have any problems with not enough scientific equipment.

2.3 Understanding and Practice about Knowledge of Science Curriculum

Science Curriculum and School-based Curriculum Are Used as Framework for Science Content, Teaching Strategy and Learning Goals

Initially, Sirod conceived that the science curriculum standard was a framework of science content. He used only science curriculum standard to know what topic of science that he had to teach for 6th graders. However, after discussing and participating with the CTM team, Sirod focused on the importance of the National Education Act and its relation to the Basic Education Curriculum and the Science Curriculum Framework. He provided an extensive reflection on his learning in his written reflective.

> …. After I participated in the analysis of the national requirements I revised my prior understanding about students' construction of knowledge. I have a better understanding of science curriculum. When I plan my lesson, I understand how to interpret curriculum and link to my lesson. Now, I use science curriculum not only for science content, I also realize about the goals for teaching and learning science described. Consequently, I conduct my understanding of the national framework to reflect the classroom teaching.
>
> (Sirod's Reflective Journal # 11: December, 2009)

In order to broaden his science curriculum knowledge, Sirod was required to work with a co-teacher to conduct school-based curriculum in the CTM III-IV. He came to the CTM meeting and shared what he had learned from preparing lesson plans with CTM team. In his understanding, Sirod felt that the discussion in

CTM central meeting helped him to have a better understanding of the curriculum. He had learned about school-based curriculum development and scientific literacy in curriculum. As Sirod stated,

> …I just realized that I should not only teach by following IPST curriculum, I should plan my lesson corresponded to school-based curriculum. The school has the freedom to integrate the school-based science curriculum, but at the end of school year, students need to achieve all knowledge proposed in the curriculum. The science strand of my school was promoting students' development in thinking process and imagination, problem-solving ability, communication skills, decision making ability, and scientific mind.
>
> (Sirod's Central Meeting# 3: December, 2009)

Additionally, in the classroom discussion he shared his understanding that school-based science curriculum was developed for science teaching. Like Malai and Napaporn, Sirod understood that the school relied on the science curriculum framework in which students in elementary school level learned science using learning standards. At the elementary school level, goals of teaching and learning science also relied on the science curriculum framework and students learned science from the standards proposed in the framework. For Sirod, the learning outcomes in strand 8 (the nature of science and technology) was new to him. At the end of CTM III, Sirod and his co-teacher had opportunities to compare and analyze science content in the Science Curriculum Framework and in school-based curriculum. From this discussion, Sirod also mentioned that he developed an understanding of science curriculum particularly strand 1, 2, and 3.

From Sirod's lesson plans, he demonstrated considerable understanding of the science curriculum including the goals of teaching and learning science, learning standards, and school-based curriculum development. His understanding was the same as Malai's. He changed his understanding and practice of curriculum by his self-study, sharing, reflecting and discussing about science curriculum framework with CTM team. Sirod also learned the development of school-based science curriculum which depended on the number of science teachers in a school. Contexts of school and local community should be integrated in school-based curriculum.

2.4 Understanding and Practice about Knowledge of Assessment in Science

Scientific Concepts, Scientific Skills, Scientific Attitude, and Attitude toward Science Are Aspects for Evaluation and Assessment of Student's Learning

Sirod gradually developed his knowledge of assessment through the CTM. As the CTM progressed, Sirod gained better understanding of aspects of student learning because of what he experienced in the CTM II activities. He learned goals of teaching and learning science from the Science Curriculum Framework. Sirod indicated that the goals and purposes of leaning science are: understanding scientific concepts, possessing process skills, creative thinking, and conceptual understanding, ability to solve problems, and have scientific minds. As he noted in his reflective journal "My lesson plans were developed by my co-teachers (Malai, Napaporn) and I. These lesson plans were on the concept of Electricity. We discussed about goals and purposes for teaching science and we expected that our students should understand and explain the concepts of Electricity; use appropriate scientific skills in experiments; conducted investigation as scientists. (Sirod's Reflective Journal# 12: December, 2009)

With regard to Sirod's instructional practices, the results presented that Sirod implemented the lessons following his plans. The first two lessons, he focused to assess students with traditional pencil-and paper tests at the beginning of lessons. These tests were developed before he participated in CTM. He improved his test as Malai did. He added space under each question for students to write their reasons "why did they answer that choice?" During his class, in the lesson of Series and Parallel Circuits, students were to investigate the difference between Series and

Parallel Circuit. He always asked students questions to explore what the students understood and facilitated them to interpret data. During the instruction practice of building electric circuit, Sirod and his co-teacher walked around the student groups and observed the students' performance showing their skills in scientific equipment. Two teachers introduced some students on parts of circuits. Additionally, Sirod's progression in an understanding of student learning in aspect of social interaction was evident in his professional experience through CTM's practice. For example, Sirod included social aspects as learning outcomes as well as conceptual aspects. Therefore, he expected his students to work cooperatively and to use scientific concepts to maintain plant diversity in students' local communities.

Summative and Formative Assessments as the Major Methods to Understand Student's Learning in His Classroom

Like Malai, Sirod also developed his understanding of summative and formative assessment methods through sharing, reflecting, and discussing among CTM team. For summative assessment, Sirod thought that there should not be multiple choice tests. Written tests and oral examinations might be alternative assessment methods for teachers, and he thought that these methods helped the teachers get into what students really understand. Regarding Sirod's classroom observations, Sirod and his co-teacher (Napaporn) used written tests to assess student learning. Sirod showed the flashlight and he then asked students to draw the flashlight circuit. As Sirod mentioned after his class "I think that the assessment method can help me understand more about the students' prior understanding of Electric Circuit". Moreover, in Sirod's instructional practices, worksheets and mind mapping were also used to identify students' understanding after finishing his lesson. Sirod' reflection on the teaching with co- teacher during discussion of CTM central meeting indicated that he had learned and developed his understanding of formative assessment. He thought that formative assessment should be used to probe students' prior knowledge and their development of knowledge in the lesson. With regard to Sirod's practice, students were asked questions that related to their daily lives, as evidence "when you want to turn on a lamp, you do not want it to stay on forever. To turn an electrical device on or off, you have to open and close a circuit. How does the circuit open and close?" (Sirod's Central Meeting# 3: December, 2009)

In summary, Like Malai and Napaporn, Sirod developed his knowledge of assessment in both aspects of teaching; understanding dimension of student learning, and assessment methods. He appeared to be more focused on inquiry-based learning as a teaching strategy. He thought asking students questions, observing their behavior, and getting more interaction were important alternative assessment methods. His knowledge of assessment was influenced by sharing, reflecting, and discussing on teaching and learning based on science educational reform during CTM progression.

2.5 Understanding and Practice about Knowledge of Learner and Learning

Students' Prior Knowledge and Difficulty Are Probed during Co-Teaching

During central meeting, Sirod told CTM members about how he explored students' prior knowledge. The first lesson, he asked students to answer questions before starting a lesson. For the third lesson, students wrote their experience and prior knowledge on Post-it notes. Last lesson, students created mind mapping using vocabularies that Sirod provided to them. After every lesson, students and Sirod discussed the results of the investigations. Sirod asked the students the main investigating questions (scientifically oriented questions) again. He had the students compare the findings with their previous answers that they wrote in their worksheets, Post-it notes, or mind mapping. As Sirod mentioned "Students were engaged to connect the results with their previous understanding. When they could identify what they had missed from the result, they changed their conceptions. Therefore, they learn science. Student's learning was showed by their work. I checked their understanding of science through their answers, worksheets, and mind mapping" (Sirod's Reflective Journal# 14: January, 2010). To increase students' learning in science, mind and concepts mapping were integrated to Sirod's teaching practice. In CTM III, Sirod also had a chance to share, reflect, and discuss on CTM members' teaching. He participated in microteaching activities in which the CTM members played the role as a school teacher, teaching the concepts of Electricity. After the microteaching, Sirod shared his ideas about the instructor's teaching, especially about the importance of students' prior science conceptions. He used questions to ask students' prior knowledge. He shared his ideas about science concepts related to teaching the Electricity concepts:

> …I think before learning this topic [Electricity], students should learn the concepts of those atoms have protons, electrons, and neutrons. After learning this topic, students should learn the concept of magnetism
>
> (Sirod's Central Meeting# 3: December, 2009)

This understanding of science conceptual framework related to his curriculum knowledge. Since Sirod had a better understanding of the science curriculum especially in sequencing science concepts in elementary school teaching, he could apply that understanding to identify which prerequisite science concepts students should know before teaching specific science content. Sirod learned that students had their own prior knowledge before learning science and this knowledge was important for teaching. Sirod noted this idea in his reflective journal. From the teaching experience, after his class, Sirod discussed with the researcher about his implementation of the lesson. He mentioned that "I thought the lesson introduction was aimed at eliciting student prior knowledge that could guide teachers' teaching in the next steps". (Sirod's Interview# 9: January, 2010)

Sirod's Knowledge of student learning came from co-teaching observation. Throughout the CTM, Sirod had opportunities to co-planning,-teaching and-evaluating with other co- teacher's teaching in real classroom situations. Every week after co-teaching, Sirod came back with information to discuss with CTM members in central meeting. His ideas about co-teaching were reflected in his better understanding of student learning. He had learned that science teaching should be flexible and meet student grade levels and their learning style.

Different Students Are at Different Levels of Abilities and Interests

From Sirod's reflective journals after CTM I: exploration stage, he realized the importance of individual student differences in classroom teaching. Sirod felt that it was not good to separate high ability students from low ability students, because the teacher might not take care about the low ability students. He thought that high ability students in each group were the only ones who did activities, while low ability students did not have a chance to participate in the activities. Consequently, Sirod kept clustering students by mixed genders and abilities. Consistent to Sirod' lesson plans created after he got professional experience, the results showed that Sirod had started to do students' portfolios for science subject. He collected students' profiles, students' works, and students' examination results. The students' profiles had information of each student (name, gender, birthday, and interesting hobby). Sirod designed his lesson plans intergrading learning stations to the third lesson plan that he co-taught with Malai in topics of open-closed circuits and series and parallel circuits. He prepared various activities for diverse learners. In the fourth lesson plan, he adjusted his teaching strategies using the students' parents as the second teacher at home. As Sirod stated,

> …Learning should not happen only in school and the teacher can be the students' parents or person that students have interaction with. Teachers should use differentiated teaching to support diverse learning needs. I think all students are different in terms of their achievement, ability, learning and cognitive styles as well as attitudes, pace of learning, personality and motivation. Using differentiated instruction, teachers should cater to a wide variety of varied interests, students' backgrounds and world knowledge which results in more dynamic classroom interaction. So, I also provide students some activates that they can go back home and learn with their parents such as

> interviewing elderly people about how they lived without electricity when Thailand did have electricity (Sirod's Interview# 9: January, 2010)

In Sirod's teaching experiences, he provided various activities for all students who did not learn in the same way. In addition, it was common for a class of students to be at a variety of levels. Sirod used different teaching methods in order to reach all students effectively. During Sirod's teaching class, inquiry-based teaching, cooperative learning, and problem solving were prominent strategies that he often intergraded into his lessons.

Students Are Active Investigators and Creative Thinkers

After Sirod received the professional development experience, he conceived that students in science classroom should be active learners, Mind-on investigator, and creative thinker. He suggested to CTM team that the instructor and the learners should be equally involved in learning from each other. As he mentioned,

> …I taught students by giving them main role of teaching and learning. Students were provided opportunities to do investigations. They started the lesson from things that the students see in their daily lives. Nowadays, technology develops very fast. Most students know how to use computers and search information from the internet. I also learnt from my students through their work (Sirod's Card Sorting# 4: January, 2010).

With regard to Sirod's lesson plans, the results confirm that Sirod provided students activities that the students work as an active group and they designed their experiments and investigations by themselves. Sirod was the consultant and facilitator for them when they had problems or questions. Some activities students were encouraged to work with their parents such as students interviewing family members for examples "how to live without electricity? How do people reduce electric bill?" Sirod's teaching engaged students conduct Hand-on activities, design creatively, think critically and logically of the activities, and significantly know the main problems or questions that their groups would like to find the answers and understood the purposes that were addressed in the activities. He asked the students motivating questions to them think in aspect of investigative design.

Teachers Play Multiple Roles as Major Factor for Successful Teaching

In CTM II, Sirod told CTM members about of his teaching experience. His initial teaching style was like a lecturer and explainer because Sirod understood when the students who paid attention to teachers; they would influence their understanding of science concepts. Like Malai, Sirod was curious why his students might not pass a test when they could answer the teacher's questions in class. Students seemed to understand the content very well during his class, but they could not pass the examinations. Sirod discussed this problem with other CTM members. The CTM team agreed that this problem happened because students might not understand what they learned. They only tried to remember what they learned. That memory recall would not stay with them over at long period of time. As Sirod mentioned "I felt that the students only understood the conclusions made about the concepts, but did not know the reasons behind the conclusions (Sirod's Central Meeting# 2: November, 2009). In CTM III: co-planning stage, Sirod expressed that he should play in various roles, starting from a preparer of teaching and learning materials, a prober of students' prior knowledge, a motivator of students' interests and curiosities, an advisor of students' investigations, and a facilitator of students' learning. With regard to Sirod's teaching practices, the findings revealed that his practices were considerably aligned with his understanding. However, sometimes Sirod used director and lecturer roles for concluding his lessons after classroom discussion.

In summary, Sirod's development of knowledge of student prior conceptions and learning was noticeable when he appeared to recognize the importance of a student's prior knowledge and individual differences in learning. He learned that the students had different science conceptions. Some students held correct conceptions but some did not. This development came from reflection on his and others teaching and discussion about student learning during CTM experiences.

3. Sirod's Understanding and Practice about Knowledge of Context

School and Community Contexts Are Integrated into His Teaching Activities

From Sirod's lesson plans, the results showed that he created several activities in worksheets related to students' local communities according to suggestions that came from the CTM group. Especially in exercises, students were provided news to read, events, or articles that happened in students' local communities. Sirod used these activities for engaging students' curiosities and promoting students' thinking.

With regard to Sirod's instructional practices, he engaged students by asking the questions that were related to their context e.g. "what would happen if we did not have electricity because we ran out of coal? How can we produce electricity that is friendly to the environment? Sirod said that when he asked students these questions, students were very active answerers. They had experiences from their homes and parents' jobs. After students learned the topic of Electricity, they had the opportunity to interview their family members or local people who live in the community. They then shared their information as a group. Sirod agreed with Malai and Napaporn that students could learn science wherever they might be, the students just only need to participate and interact with others (Sirod's Central Meeting# 5: February, 2010).

Summary of Sirod's PCK Development throughout the PCK-based CTM

When coming to the PCK-based CTM, Sirod expected to learn teaching skills, examples of teaching strategies to help students learn by themselves, apply their knowledge in their daily lives, and activities that could cover the content, science process skills and scientific attitude that students needed to learn. He experienced science learning in elementary school that relied on a teacher-centered approach. Sirod was a reflective practitioner, and very open during classroom discussions and in the reflection written in his journal entries. His initial understanding and practices of PCK in aspects of subject matter knowledge, pedagogical knowledge, and knowledge of context were not based on constructivism. He had problems with his knowledge of science content because he did not graduate from the area of science education. Sirod just moved from teaching agriculture subject to science subject. He was not familiar with engaging students to learning science. When the researcher provided him the CTM professional development, he immediately accepted to be one of three research participants. Sirod is a very creative teacher in teaching activities. The activities were very interesting and challenged the students but the activities and exercises still supported a teacher-centered approach. Sirod's initial lessons focused on students' learning science content and process skills as the major teaching and learning goals. From the first interview and card sorting, the results showed that Sirod also intended his students to have scientific skills, scientific attitude, and attitude toward science. But he did not emphatically mention about these aspects of goals and purpose for teaching and learning science. He relied subterranean on students' applications of scientific knowledge into their daily lives, family, and community. In addition, Sirod also stated about the nature of science as learning goals and purposes (definition of science, tentativeness of scientific knowledge, characteristics of scientists, and interaction of science-technology-society) relied on contemporary, and constructivist understandings. His understanding and practices about teaching and learning science centered on contemporary constructivist understandings in which his goals for learning science were to understand and explain natural phenomena, and bring scientific knowledge to apply and use in a positive way for student's daily life. In his teaching practice, he thought teaching and learning science through inquiry approach based on constructivism, should give students chances to learn by themselves, and touch real things.

Sirod's initial PCK knowledge base was limited. He had not learned about the science curriculum, so his prior knowledge of the curriculum was not strong enough for his teaching practice in a real classroom. Even though his understanding and practices about teaching and learning science were contemporary constructivist, his knowledge of student learning and teaching strategies was based on positivist understandings. In his first teaching activity in CTM I about the Biotic and Abiotic, Sirod rarely focused on prior knowledge and learning, and most learning activities were based on lectures. Initially, he was frustrated with the ideas of student-centered teaching. His knowledge of assessment centered on conceptual knowledge and heavily emphasized non-specific assessment methods. He especially paid more attention to paper-pencil tests and workheets for evaluating students' learning at the end of a course. Therefore multiple choice tests were easier for his learning assessment.

As the CTM progressed, Sirod's PCK knowledge base gradually broadened through learning activities in the CTM. Sirod was provided with many opportunities to broaden his understanding and practices about teaching, learning and the nature of science. He had a chance to express his initial understandings and compare these understandings to constructivist understandings of teaching and learning science, proposed in the Basic Education Curriculum, and the Science Curriculum Framework. Sirod was provided interesting ideas from the CTM members through sharing, reflecting, and discussion during his co-planning, co-teaching, and co-evaluating. Through these activities, Sirod's understanding and practices of PCK supporting teaching and learning science based on constructivism shifted to more constructivist understandings specifically, in the nature of scientific knowledge. Sirod's understanding of science curriculum was influenced by analyzing and discussing the science curriculum framework and from the reflection with the CTM team about school-based science curriculum. Like his co-teachers, Sirod thought that reading the Basic Education Curriculum and the Science Curriculum Framework did help his understanding of the science curriculum. He showed that when he analyzed content the Science Curriculum Framework, discussed, and reflected his ideas with the CTM members about school-based curriculum development, Sirod came to understand more about goals of teaching and learning science, learning standards, the school-based curriculum, basic science and advanced science. Additionally, observation of the co-teacher's teaching and discussion of student prior knowledge and learning enhanced Sirod's awareness of the importance of student prior knowledge and individual differences in learning. He learned that the students held different science conceptions.

Sharing, reflecting, and discussing during co-planning, co-teaching, and co-evaluating of CTM were key activities in the CTM that enhanced Sirod's PCK development. Through participating in the CTM, Sirod's understanding about student-centered learning became clear. In his broadened ideas, student prior knowledge, and participating in hands-on activities were key aspects of student-centered teaching. Sirod also had a chance to clarify his understanding of how to integrate knowledge bases for teaching particular content. Sirod reflected on his own teaching skills that helped him become aware of the importance of each knowledge base for teaching and its integration. In his second lesson plan about the Conductors and Insulators, learning goals and purposes, learning activities sequence, instruction media, and assessment methods, had more detail and were more interrelated. He appeared focused more on teaching science by inquiry approach and enhanced students to learn science by cooperative learning as one dimension of student learning He used a variety of assessment methods such as asking questions of students, observing their behavior, creating mind mapping and interaction with them. These student-student and student-teacher interactions appeared in his microteaching activity. When he brought his PCK into teaching practice, Sirod's microteaching with his co-teachers showed his development in understanding and practice of PCK for constructivist teaching and learning gradually. Sirod was an open minded teacher. He improved himself by accepting CTM members' comments and suggestions. For the four times of co-teaching, Sirod showed the CTM team that his classes were very developed, contained a friendly and comfortable environment, interesting teaching and learning activities, and various types of assessment methods.

CHAPTER V

RESULTS FROM THE CROSS-CASES ANALYSIS

Introduction

This chapter presents the results of three case studies after the participant teachers engaged in the CTM. The chapter aims to address the research question: What are the teachers' developments of understanding and practice of PCK?; How did the teachers change their understandings and practices of PCK after they engaged with CTM.; and What factors constrain or support elementary science teachers while implementing the PCK based CTM? To answer the questions, data was gathered from multiple sources including individual interviews, card sorting, teachers' inquiry-based lesson plans, classroom observations, teachers' written reflections, and central meetings. The data was initially examined within-case analysis and was represented in Chapter IV and then followed by cross-case analysis presented in this chapter. This report was examined by considering the individual teachers' understanding and practice of PCK according to the aspects of the essential features of PCK: subject matter, pedagogical knowledge, and context. The results of this chapter are presented in common findings across the three cases. Lastly, a discussion of the results is provided. Pseudonyms were used to represent the upper elementary teachers' names used in previous chapters.

Three Case Studies' Background

The findings from the three teachers showed that three of the participants did not graduate from a science education programmed yet they were required to teach science. They said that their non-teaching assignments had taken more time than their teaching responsibility. As information below;

Table 5.1 Participants' Background Information

Participant	Educational Background	Years of Teaching Experience in Science	Grade Level	Prior Work Experience
Malai	Social Education[a]	3	4	Social Subject
Napaporn	Physical Education[a]	11	5	Physical Subject
Sirod	Agricultural Education[a]	1 year and 11 months	6	Agricultural and Social Subjects

[a] Undergraduate Degree

The results from the three teachers showed that even though they attended many workshops, they still had a lack of learning materials, a lack of time for covering all science concepts, a lack of some science content knowledge, and a lack of how to interpret the theory into practice. Their reason for participation in the CTM was they realized that inquiry-based teaching and learning was an effective approach for teaching and learning science. To participate in the CTM, they expect to learn new techniques and/or strategies for teaching science through inquiry and know how to assess student's learning.

The Three Elementary Science Teachers' Developments of Understanding and Practice of Pedagogical Content Knowledge

For the first semester [CTM I] in year 2009, three case study participants were engaged to share, discuss, and reflect on their existing understandings and practices of PCK. The changes of understanding and practice of PCK that three teachers held during CTM progression are presented below.

1. Elementary Science Teachers' Developments of Understanding and Practice about Subject Matter

The findings from the three teachers showed that all of the teachers perceived that they were still lacking science knowledge in some topics**.** The results showed that the three teachers were not confident about content what they taught to their students. All teaching was based on textbooks and teaching manuals. The three teachers said that they did not graduate with a science background. They had to teach science subject because there were not enough science teachers for the elementary level. Two teachers, Malai and Sirod, mentioned that they were new to teaching science and they were not confident in science content. The teachers had alternative concepts and still taught science by transmission. Sirod was the teacher who had the least amount of experience in teaching science. He revealed that he mainly used lecturing because students would learn the right concept. Napaporn said that she had strong science content from the many years of teaching science. However, the findings from various data sources revealed that the three teachers were not confident in the science content that they understood and taught to their students. From their perspectives, they believed that their ability to teach science concepts would be better if they knew more science knowledge.

After CTM progressed, their understandings and practices of PCK showed that the three science teachers gradually acquired more understanding in science concepts through sharing and discussing with CTM Team. Napaporn and Sirod mentioned that they understood more science concepts when they discussed the concepts with CTM team members. Malai agreed with that and also presented that she increased her science knowledge by planning lessons with her co-teachers. In the classroom, teachers showed that they changed from teaching science by reading textbooks to asking students with questions and discussing the concepts with them. Malai had more science knowledge. She could link the results from experiments and investigations to science concepts. Sirod and Napaporn had the same ability as Malai in linking results from experiments to concepts. Consistent with their practices, students were encouraged to study science based on the concepts that they learnt from previous classes.

2. Elementary Science Teachers' Developments of Understanding and Practice about Pedagogical Knowledge

This section presents three teachers' developments of understanding and practice of pedagogical content knowledge. The results were presented in five aspects of knowledge: knowledge about goal and purpose of science teaching; knowledge about teaching method; knowledge about science curriculum; knowledge about learning and learner; and knowledge about assessment.

2.1 Development of Understanding and Practice about Knowledge of Goal and Purpose of Teaching Science

The findings across all three case study teachers showed that the teachers consistently realized that providing students with opportunities to learn science based on educational reform was important. They accepted that they should emphasize their inquiry-based lessons on scientific knowledge and science process skills in accordance with the NSCS. They had the understanding that teaching and learning science through inquiry approach was happening in their classrooms. Students should learn science content; have proper science process skills; and possess a scientific attitude. In addition, they also mentioned the nature of science as teaching goals. However, the three teachers did not focus their lessons on scientific attitudes when they were teaching in their real classrooms. They taught science to students with what they understood about the nature of science. Students were encouraged to learn science content and practice science process skills. Only one teacher, Napaporn, referred to scientific literacy for science teaching. Her targeting of teaching scientific knowledge was to apply that knowledge into the student's daily lives. However, Malai and Napaporn do not set the goals that are concern about attitude aspect for teaching and learning. All three teachers taught science only to promoting students learning of science knowledge and science process skills.

In summary, the three participants had an understanding about the goals of teaching science in line with the reforms that focused on learning scientific knowledge. The target covered both the science of teaching knowledge and ability to think and conduct experiments. Bringing science knowledge to use in the daily life of the students did not encourage the students to become more aware of the relationship between science and technology nor their impact in current society and the environment as the conclusion of major and minor goals for teaching and learning science of three teachers during CTM I that was represented on table 5.2 and figure 5.1.

Table 5.2 Major and Minor Goals for Teaching and Learning Science

Teachers	**Goals of Teaching and Leaning Science Subject**	
	Major Goals	**Minor Goals**
Malai	- Develop conceptual understanding of subject matter - Develop scientific skills and techniques to understand scientific concepts - Be prepared for high school academic	- Wonder and appreciate the complexity of life - Use scientific concepts in daily life - Develop positive science attitude
Napaporn	- Develop conceptual understanding of subject matter - Develop scientific skill - Become useful, productive, informed citizen	- Develop positive science attitude - Be successful in school and life - Develop environmentally based decision-making ethics
Sirod	- Develop conceptual understanding of subject matter - Develop laboratory skills - Be successful in elementary science teaching	- Maintain positive attitude towards science - Develop life skill (i.e. Basic Literacy Skill) - Develop belief in personal success

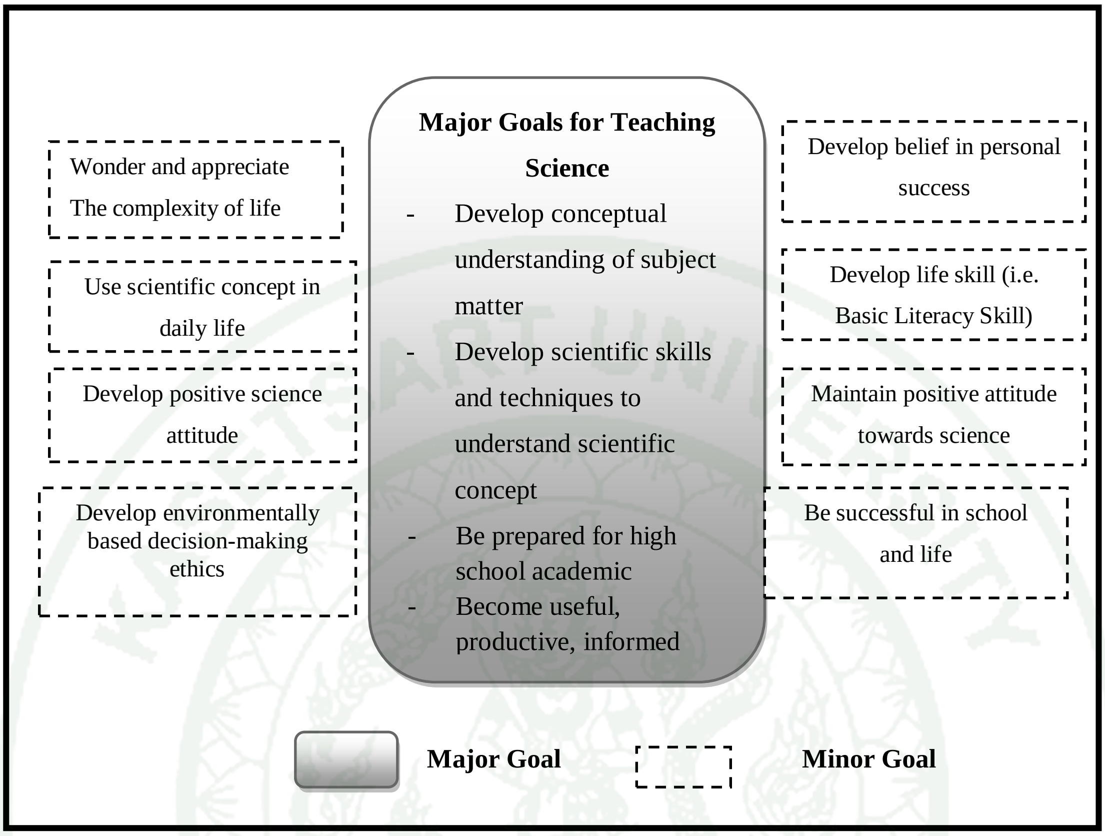

Figure 5.1 The Diagram Shows Three Cases' Goals of Teaching Science.

As the CTM progressed, the three teachers changed their focus to developing students' scientific knowledge, science process skills, and scientific attitudes. The findings from the three teachers revealed that, for most part, the teachers' teaching practices aligned with their understandings about instructional objectives. In general, the results showed that the three teachers' understandings and practices regarding the instructional objectives were broadened. After experiencing the CTM II, the three teachers recognized that they should focus their lessons on scientific knowledge, science process skills, and scientific attitudes. The teachers' development was compliant with the goal of science teaching and learning in the NSCS. The changed understandings and practices regarding the instructional objective of all teachers were maintained throughout the four phases of the CTM.

2.2 Development of Understanding and Practice about Knowledge of Instructional Strategies for Teaching Science

In CTM I, three science teachers understood that students should be motivated to learn science by their interest; however, in practice the teachers started the lesson by telling the student what topic they would learn. The findings from the three teachers showed that all three teachers understood that they should introduce an inquiry-based lesson by motivating students' interest. However, the teachers' practice was varied. For Malai, she introduced her inquiry-based lessons by motivating students' interest as well as providing students the concepts of study. Napaporn and Sirod introduced their lessons by motivating students' interest, telling students the concept of study and clarifying the main question to investigate. For Malai, she used teaching media mainly to motivate students' interest. However, the three teachers did not elicit students' prior knowledge of the concepts being studied. Additionally, three teachers did not understand that they should link students' interest to scientifically oriented questions.

After CTM II-IV, the teachers begin an inquiry-based lesson by motivating students' curiosity and clarifying a scientifically oriented question. The findings across the three case study teachers showed that the teachers' teaching practices agreed with their understandings. In particular, the three teachers' understanding and practices regarding classroom lesson introduction. All three teachers agreed that it was important to motivate students' interest in the concept being focused upon and clarify the questions in which students were expected to answer. They realized that they should also elicit students' prior knowledge. Along CTM development, the three teachers began to change their understandings and practices. Napaporn and Malai began to change their understanding of clarifying scientifically oriented questions and eliciting students' prior knowledge after attending the CTM II. Sirod came to accept the idea of eliciting students' prior knowledge after he engaged in the CTM IV.

From the exploration [CTM I] the three teachers had some existing understandings and practices that students should learn science by doing and the teacher should provide various investigations or experiments for teaching activities. All three teachers understood that in inquiry-based teaching and learning, students should learn science through hands-on investigations. However, the teachers held different understandings regarding who should be the person that designs the investigations. For Napaporn, she understood the investigation could be developed by the teacher, students, or both parties. Unlike Malai and Sirod that believed the investigation and experiment could be designed by the teacher or students but mainly by the teacher. The three teachers now understood that students should be responsible for designing the investigation first and teachers should be facilitators. In addition, the three teachers consistently agreed that they should provide students scientific knowledge before allowing them to conduct the investigation. With regard to the three teachers' teaching practices, the findings indicated that there was not an agreement between the teachers' practice and their understanding. The three teachers had students learn science through hands-on investigations; but, the investigations were devised only by the teacher. Students were assigned to do the investigation by following the teachers' procedures.

After CTM progressed, the three teachers' changed their understandings and practices such that the investigations could be developed by students and the teacher should act as a facilitator. The experiments were developed by the teacher or both the teacher and students. In their practices, all teachers provided the opportunity for students to design the experiment. Students were challenged to design investigations for answering questions that they and the teacher set as the main questions. After the students got their results, they were asked to make conclusions/explanations. After the teachers participated in CTM II- IV, they changed their focus on students being responsible for analyzing data and formulating conclusions. Teachers should be facilitators, motivators, questioners, and sometimes leaders. Their understandings and practices regarding how the teacher made the conclusions and explanations developed after they experience in CTM II-IV. The findings across the three case study teachers indicated that all of the teachers conceived that in inquiry-based teaching and learning students should be responsible for analyzing data and formulating conclusions. After reaching a conclusion in each investigation, the three teachers changed the focus on making a connection between the conclusion (new knowledge) and students' prior knowledge. With regard to the teachers' teaching practice, the findings revealed that there was consistency between the teachers' practice and understanding. In CTM III students were responsible for analyzing data and formulating conclusions. The findings across the three teachers indicated that all three teachers maintained their understandings that students should take an active role for analyzing data and formulating conclusions. The students should also formulate that conclusions generated were based on data obtained from investigations. In Napaporn lessons, students had the chance to analyze data and formulate conclusions on their own. Unlike Malai and Sirod, the students analyzed data and formulated conclusions together with the teachers. In the stage of communication, the three teachers had same understanding that students should share their data and conclusions with others. However, the three teachers' teaching practice was somewhat different from their understanding in CTM I. After they attended CTM for two semesters, the findings across the three case study teachers showed that all of the teachers maintained their understanding in that students should share their data and conclusions with others. The aim of the sharing was to provide students a chance to evaluate and justify their data and conclusions with the other groups of students. In addition, for Napaporn, this type of student communication also helped students to learn to listen to and accept other people's opinions. Their teaching was consistent to their understanding. However, in Sirod's classroom instruction, there was one lesson that students did not have opportunity to justify and evaluate their conclusions with alternative ones since there was no data collection in these lessons. Unlike Napaporn and Malai, lessons always focused on encouraging students to discuss their conclusions on flip boards. Malai had students communicate their data with other groups of students and she also let students write their conclusions on flipcharts. The three research participant began to accept that communication was not only the way students learned knowledge but it was also the way they learned to listen to and accept others' opinions (scientific attitude).Therefore, the students had opportunities to justify and evaluate their conclusions in comparison to alternative conclusions.

The three teachers' understandings and practices were consistent with one of the essential features of classroom inquiry (NRC, 2000). According to the NRC (1996: 27), learners communicated and justified their explanations with others. The NRC indicated "sharing explanations provided others the opportunity to ask questions, examine evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations."

When comparing the level of the three teachers' development of their understandings and practices concerning aspects of knowledge in the instructional strategy, the findings indicated that three teachers tended to design their lessons to be more learner-directed inquiry. However, for the first lesson that was during co-planning stage, Sirod still mainly used teacher‘s directions more than students' inquiry. He adjusted his understanding and practice by co-teaching with Malai who provided him with different opinions. Therefore, Sirod's first lesson was transitory constructivist teaching and learning.   However, in CTM III the result presented that the teachers had constructivist understanding dominantly in the last two lessons. They gradually changed their understandings and practices of PCK that was consistent to constructivist teaching and learning.

When using group work the three teachers maintained their understanding of teaching and learning science by working as groups. Students should learn science in a collaborative group. Since CTM I- IV, the results showed that the teachers had developed their understanding and practice that students should learn science in groups. For Napaporn and Sirod, they changed their understandings and practices to focus on students completing the task and working cooperatively in groups. . The three teachers had the same understanding that too many members in a group might impact the students' effectiveness in terms of learning outcomes. Group sizes should be between 5-6 students. The findings across the three case study teachers revealed that, their understandings and practices were changed from their initial understandings and existing practices. After having the professional development experience, the findings also indicated that the three teachers began to improve their understandings and practices regarding group work at different stages during the professional development program. For Napaporn, her understanding was more focused on students' interaction among group members after completing the CTM. Malai and Sirod began to conceptualize the idea after experiencing the CTM II-IV. The three teachers' understandings and practices aligned with the social constructivist's perspective in that individuals constructed meaning of what they experienced through interactions with each other's (e.g., teachers and peers) and with the environment they lived in.

After engaging in the CTM, the three teachers understood that students should be learning inquiry-based lessons by motivating their interest. Students and teacher should work together for clarifying problems or questions to investigate. Malai, Napaporn and Sirod also knew that they should elicit students' prior knowledge of the concept being focused on. The teachers' understandings were consistent with the 5Es inquiry process (DCID and IPST, 2002). The more time the three teachers spent in CTM, the more they changed their practices to be consistent with their understanding. The teachers developed from posing their own questions to blending the students' questions regarding the investigative questions. Corresponding to the NRC (2000), learners were engaged in inquiry-based classroom through scientifically oriented questions. The NRC (2000: 24) defined, "scientifically oriented questions are questions that lead themselves to empirical investigation, and lead to gathering and using data to develop explanations for scientific phenomena." The NRC also noted that the questions must be able to be addressed by students' observations and scientific knowledge gathered from reliable resources. After CTM proceeded, the results showed that Sirod emphatically changed to probe students' prior knowledge to align with the constructivist perspective.

Malai, Napaporn and Sirod also expanded their understandings and practices related to students answering scientifically oriented questions through conducting experiments, review of information from reliable sources and doing a survey. The three teachers' understanding aligned with the DCID and the IPST (2002). According to the DCID and the IPST (2002), scientific investigations are defined as methods for acquiring scientific knowledge. These methods required students to collect data, think logically, formulate hypothesis (or prediction), interpret data, and generate explanations. The DCID and the IPST suggested that there were various methods of scientific investigation teachers could use in inquiry such as observation, survey, experimentation, and review of information from reliable sources. This understanding also corresponded with the NRC (2000). According to the NRC (2000), scientific investigation could be developed by teacher, students, or both parties, depending on the expected outcomes. After receiving the professional CTM experiences, the three teachers maintained the same notion that students should be responsible for analyzing data and making conclusions. In addition, their practices began to link conclusions to students' prior knowledge. The three teachers' understanding aligned with the BSCS 5Es instructional model (Bybee *et al.*, 2006) and the 5Es inquiry process (DCID and IPST, 2002).

When comparing the time in which individual teachers began to develop their understandings and practices in relationship to the four aspects of the essential features of inquiry-based teaching and learning, the findings indicated that all three teachers seemed to develop most of the essential features of inquiry after experiencing the CTM II-IV and maintained these new understandings and practices throughout the CTM. The findings showed that the teachers began to corporate many of the key components of inquiry-based teaching and learning after they completed the CTM II. Napaporn was the teacher who had the most experience in teaching science compared to Sirod and Malai. Therefore when they co-taught in the classroom, Napaporn could share her experience with others. In turn, Napaporn learned many things from Malai and Sirod such as new subject matter, teaching media, and technology.

2.3 Development of Understanding and Practice regarding Knowledge of the Science Curriculum

In CTM I, the findings from cross case analysis showed that only Malai did not focus on teaching science based on school-based science curriculum. Unlike Napaporn and Sirod they thought learning and teaching science should be based on school–based science curriculum because they understood that different schools had different contexts. After the CTM experience, they changed their understandings and practices so that school-based curriculum should be integrated into inquiry-based lessons often as a framework for teaching goals, science concepts, and science processes. With regard to their practices, the results showed that their understandings and practices were consistent; in addition, the results also revealed that students should be motivated to learn science so that the students develop scientific attitudes and attitudes toward science as a component of their teaching goals. Their understandings and practices were consistent with the goals of the school-based science curriculum which focused on students being a curios person and ideal citizen for the community and the nation.

The three teachers agreed that the process of sharing, reflecting, and discussing in CTM motivated them to learn more about the science curriculum and to know exactly how to implement the curriculum into their classrooms that held different contexts. In their practices, school-based curriculum were used as a lesson's framework in aspects of goals, content, and process skills that students must learn in each grade level.

In summary, initially the teachers' knowledge of the science curriculum was somewhat consistent with reformed education. The more the teachers participated in the CTM experience, the more they learned about the science curriculum. They had learned about the school-based science curriculum and the science curriculum framework through reading and discussing the contents in the National Education Act 1999, the Basic Education Curriculum, and the Science Curriculum Framework. After CTM II-IV, Malai and Sirod integrated School-based Science Curriculum into their lesson developments. For Napaporn, she initially understood that the School-based curriculum was important for student learning however she mainly used the Science Curriculum Framework as the major resource for developing her lessons. After the three teachers experienced CTM, they changed their understanding and practicing about knowledge in the curriculum. The teachers developed their lessons based on both the School-based Science Curriculum and the Science Curriculum Framework.

2.4 Development of Understanding and Practice about Knowledge of Assessment in Science

As the CTM progressed, Malai, Napaporn and Sirod changed their understandings and practices about knowledge of assessment from focusing on evaluating and assessing students' learning through assignments, worksheets, and tests, to using various assessment methods for formative and summative assessments such as concept mapping, learning journals, group checking and portfolios.

In CTM I, all teachers explored their initial understanding and practice about knowledge of assessment. The results revealed that even though they expected the students to learn scientific knowledge and scientific process skills, the methods of assessment employed were not consistent with their intended learning outcomes. They used assignments and students' answers in worksheets to assess students' conceptual understanding; however rarely made corrections or gave any feedback to students to develop their understanding of progression in student learning. Students' work was checked only for classroom participation. In addition, the assessment tools employed were not related with their intended learning goals and purposes. The main concepts of the assignment did not examine some key aspects of teaching's goals and purposes for teaching science. For Napaporn, she was not sure whether students' answers could give her information of the students' conceptual understanding, and the students' development of scientific skills or that the students simply copied the assignment. Malai and Sirod mainly used multiple choice tests to assess students. Most times they used the test at the end of class to assess the score their students' received. In summary, Malai, Napaporn and Sirod emphasized only conceptual understanding and developing of scientific skills as their students' desired learning outcomes. The assessing tools that were used for assessment were paper tests or work sheets of assignments that clearly delineated the right answer. In addition, asking questions was often used when the teacher interacted with students during classroom observation.

They was not very concerned as to how or why the students answered as they did, however they were more concerned about the correct responses from students. Receiving the correct answers from students was considered to be more important than creating better questions to prompt student thinking. After professional development experience, all teachers had developed their knowledge of assessment, including dimensions of student learning and methods of assessment. The results showed that as the CTM progressed, Malai, Napaporn and Sirod gradually changed their knowledge of assessment including their teaching practices. They had developed an understanding of various dimensions of student learning and methods of assessment. In their understanding, students should develop their inquiry processes and scientific minds. Formative assessment was realized by the three teachers as an important way to learn how their students progressed in learning. They realized that assessment of student learning should be an ongoing process occurring throughout teaching and learning activities. Students should not be assessed only at the beginning or the end of the teaching class. For Napaporn, she emphatically changed to develop and use various methods of assessment. Unlike Sirod, he still mainly used multiple choices tests. However, he also observed student learning and made note of his own observation of student learning and using concept mapping. With regard to teaching and assessment practices, the results showed that Malai, Napaporn and Sirod were aligned with their initial understandings. In CTM III-IV, the results revealed that their expectations of students' learning in science consisted of three aspects: science content, science process skills, and scientific attitude and they were able to develop assessment strategies that were consistent with these expectations. Consequently, the three teachers used various types of assessments methods emphatically in their last two lessons such as tests, member checking, written journals, drawing, practical homework or concept mapping to evaluate students' understanding of science.

2.5 Development of Understanding and Practice about Knowledge of Learner and Learning

As CTM progressed, Malai, Napaporn and Sirod, developed an understanding and practice of PCK in various ways. They changed their understandings and practices to focus on the teaching of students through scientific processes. Students can learn the concept through scientific experiments and practice skills in scientific processes that would lead to scientific knowledge. The students were part of the learning process. In their initial understanding and practice about knowledge of learner and learning, students could learn science by doing. In the CTM I or exploration stage, the teachers were studies what their prior understandings and practices of PCK and the findings revealed that the three teachers consistently agreed that the role of the teacher in inquiry-based teaching and learning was that of guide and motivator. They also understood that different students had different learning abilities. However, their practice was different. Specifically, Napaporn and Malai understood that the teacher role in inquiry-based teaching and learning was that of guide and motivator. However, in practice, in addition to a guide and a motivator, they were also an activity director and a lecturer. For Sirod, he thought the role of the teacher included guide and facilitator; however, in practice, he played multiple roles in his lessons. These roles included activity director, guide, motivator, facilitator, and lecturer. For the students' roles, the findings from the three teachers revealed that all the teachers understood that the role of the students was to be an active investigator. However, there was a variety of teaching practices among the three teachers. Napaporn's and Malai's classroom instruction was aligned with their understanding. Both teachers understood the students' role as an active investigator. However, they did not see the role of the student as a minds-on investigator. Students learned science as active investigators who conducted investigations following the teacher's instruction. Learning activities of the students was measured by a variety of activities. From the teachers' understanding, it was revealed that the teachers used focus group activities that allowed students to learn through trial and error. But too often the trial consisted of a teacher describing the process as well as demons rationing the experiment to the class. For Sirod, he understood that the student's role was that of active and minds-on investigator. However, his practice consisted of students played the role of passive investigator. It was evident that learners preferred to listen and to write from the lecture.

After Malai, Sirod and Napaporn participated in CTM, the findings across the three teachers revealed that, for the most part, the teachers' understandings were consistent with their practices. Malai, Napaporn and Sirod each developed their understandings and practices regarding the teacher's role and the student's role. Both teachers' understandings and practices were developed, more or less, from their initial understandings and existing practices. The three teachers understood that there were multiple roles of the teacher in inquiry-based teaching and learning. These roles included guide, motivator, facilitator, and activity director. This finding agreed with Dewey (1938 cited in Barrow, 2006) in that he thought the science teacher should play the roles of guide and facilitator. Dewey also pointed out that students should be promoted by students' attentiveness. It agreed with the NSCS (DCID, 2002). According to the NSCS (DCID, 2002), science teachers should design learning activities that promotes students to learn science through an inquiry process. After the CTM, all three teachers understood that the teacher's role was multiple. Their understandings and practices changed to a more learner-directed inquiry. However, the three teachers developed their understandings and practices at different points of the professional development experience. For Napaporn, she began to accept the multiple role of a teacher after engaging in the CTM II. In the case of Sirod and Malai, they changed their practice in CTM III. Three teachers held this notion before they participated in the CTM and maintained the same understanding throughout the professional development program. Three teachers understood that the roles of students were active and minds-on investigators**.** The findings across the three teachers revealed that there was consistency between Malai's, Napaporn's and Sirod's understandings and their practices with regard to the role of the student. In general, the three teachers' understandings and practices were changed from their initial understandings and existing practices. All three teachers consistently agreed that the role of the students in an inquiry-based classroom was as an active and minds-on investigator. They perceived that minds-on investigator was similar to active investigator, with the addition that students knew the question that the investigation intended to answer, and thought critically and logically about the activities they engaged in. Their understandings were consistent with the NSES (NRC, 1996). According to the NSES (NRC, 1996), students must have both hands-on activities and minds-on experience. To ensure students experienced both hands-on and minds-on opportunities, the NSES (NRC, 1996) suggested students should describe objects and events, ask questions, construct explanations, test the explanations against current scientific knowledge, and communicate their understandings to others. They should also identify their assumptions, use critical and logical thinking, and consider alternative explanations. The teachers' understandings were also compliant with the NSCS (DCID, 2002) that specified that when engaging in inquiry, students would construct knowledge through several activities such as observing phenomena, posing questions, and doing scientific investigations.

3. Elementary Science Teachers' Development of Understanding and Practice about Knowledge of Context

In CTM I, Malai, Napaporn, and Sirod had the same understanding about knowledge of context. They indicated that community, school, and students' background should be realized and integrated in their teaching. However, in their instructional practice, even though they realized that teaching and learning science related to contexts of the community and school, they did not use any sources in the community around the school in the observed lessons. Students learned science only in the classroom and did the same activities, none of these activities responded to students' different backgrounds. They focused on a classroom environment that should be silent and students should pay more attention to doing experiments and to listening to what the teacher would like them to do. Napaporn explained when students were quiet, it was easier to manage and control them. For Napaporn and Malai sometimes they provided the opportunity for students to learn science through school resources such as the herb garden.

As the CTM progressed, the results showed that school and community contexts were integrated into Malai's, Napaporn's and Sirod's teaching activities. Their practices gradually changed to be consistent with their understanding about the importance of the students' and their community contexts. The three teachers created several activities using worksheets related to students' local communities. Students were provided activities by reading news, articles, or events that happened in students' local communities. After that the students would share their ideas with other students in the class. Napaporn used these activities for engaging students' curiosities and promoting students' thinking. Like Malai and Sirod, they changed their practice to use context of school and community in their lessons. With the experience gained in CTM, Malai and Sirod learned how to integrate school and community contexts into their inquiry-based lessons through working with Napaporn. In addition, the teachers conceived that providing a scientific environment in classroom was important for promoting student learning. Malai, Napaporn and Sirod changed their understandings and practices to consider classroom environment as another context that affected their teaching. In summary, the findings showed that after the three case study teachers experienced professional development experience from the CTM, their understandings and practices were changed in all aspects of knowledge that related to constructivist teaching and learning especially teaching science by inquiry-based teaching and learning. These results suggested that the CTM was an effective professional development program for the case study teachers in terms of understandings and practices of PCK.

The Characteristics of a Co-Teaching Model that Appeared to Be the Most Effective in Bringing about Changes in the Teachers' Pedagogical Content Knowledge

The finding from cross-case analysis revealed some important characteristics of co-teaching model that were responsible for enhancing elementary science teachers in developing their PCK. These characteristics and the evidence supporting them are described below.

Parity of Co-Teacher Is as Major Factor for Success in Teaching and Learning Science.

The result from cross case analysis revealed that Malai, Napaporn and Sirod claimed that a co-teaching partnership should base on a spirit of equality. Napaporn and Malai pointed that years of teaching experience, degree, or age should not place one teacher in a higher position of authority over the other. Sirod clarified that co-teachers' decisions were made mutually and were mutually agreed upon. All teachers mentioned that in the co-teaching model, each teacher had an equal role in planning, executing, and evaluating the lessons. Malai and Sirod explained that teachers had different strengths, skills, experiences, and knowledge to bring to the co-teaching experience, and these should not be minimized. Co-teachers should capitalize on the strengths of each partner without having one monopolize or succumb to the others based on perceived inequality.

Respect of Other Is the Best Way for Relationship Connecting.

The result from cross case analysis revealed that Malai, Napaporn and Sirod commented that co-teachers needed to be respected for their unique skills. In their co-teaching, the results revealed that each teacher had his/her professional skills and experience with whole group instruction, group management systems, inquiry-or problem-based learning, and specific content knowledge. When experienced teachers had skills and experience in individualizing instruction, developing individual behavior systems, diagnosing, and sequencing skills, their knowledge and skills were respected within a spirit of parity, co-teachers were free to offer their areas of expertise and creative ideas without fear or humiliation. Napaporn was the most experienced teacher with 32 years of teaching experience; Sirod, in contrast, did not have many years of science teaching experience. When they co-taught, Napaporn respected Sirod's opinion and they blended their understandings into real practice within the classroom perfectly.

Specific Mutual Goals of Teaching and Learning Science Should Be Articulated before CTM Starting

During and after CTM, Malai, Napaporn and Sirod thought and practiced co-teaching rested on shared goals. First and foremost, these goals were student based. Student-based goals often referred to increased academic skills, improved behavior or social skills, or increased access to the general education curriculum. Admittedly, co-teachers may be operating from different PCK. For example, a Grade 4 science teacher may be using inquiry approach with the concept of plant, while a grade 5 science teacher may be using cooperative learning for teaching the concepts associated with the earth. But through their collaboration, teaching strategies and lessons would apply to both sets of PCK. Specifically articulating student goals early in the co-teaching partnership provides direction and purpose for co-teaching and offers a measure of accountability and growth. Co-teachers may also have professional reasons for co-teaching, such as the enjoyment of learning from a peer and the co-teacher of working closely with a colleague. Certainly, one advantage of co-teaching was professional growth from sharing ideas, strategies, methods, and materials.

Shared Accountability for Outcomes of Teaching and Learning as Tool for Working Together

Napaporn, Malai and Sirod agreed that when co-teachers taught, they became joint owners of the classroom. No longer was this "Mr. Sirod's classroom" or "Miss Napaporn's students. "Similarly, the lesson was not "Mr. Sirod's lesson". Likewise, if the lesson was unsuccessful, both co- teachers should reflect on what could be done differently in the future. Malai additionally pointed out that in co-teaching, both co-teachers should share instructional and behavioral accountability for all students. In their practices, the teachers always discussed about teaching outcomes and how to make the goals successful before they went to teach in a real classroom.

Shared Resources for Co-Teacher's Lesson Plan

The result of cross case analysis accounted that the teachers not only shared their knowledge; they also contributed their teaching resources when they worked in CTM team. Napaporn and Sirod pointed out that a co-teacher, who hoarded materials and ideas, was primarily there to look good? In summary, the teachers believed that co-teaching rests on the ideals of parity and shared accountability; a co-teaching partnership was characterized by openly sharing materials, ideas, methods, strategies, and approaches. For example the experienced teacher should feel free to share an activity that had been successful with students in the past. Similarly, the experienced teacher may be aware of ways to modify experiments for students who had different abilities. Like Malai, she commented that the shared resources and expertise of both co- teachers embodies the spirit of co-teaching.

Co-Teaching as an Alternative Strategy to Develop PCK

Through the CTM, Malai, Napaporn and Sirod stated that they had learned subject matter knowledge, pedagogical knowledge, and knowledge of context through participating with CTM. These teachers gradually became satisfied with teaching and learning in the CTM. They had a better understanding of how to teach a specific science topic by integrating all aspects of PCK. Microteaching activity was one of the activities in the CTM which Malai, Napaporn and Sirod appreciated. Most of the meeting sessions in microteaching ended with critiques and discussion about student conceptions, learning outcomes in science curriculum framework, teaching strategies, instructional media, assessment methods and lesson plan. The teachers had a chance to clarify their understandings and practices of how to integrate knowledge bases for teaching particular content. The critique and reflection by CTM team on the instructor's teaching showed their awareness of the integration of knowledge based-PCK. The microteaching activity helped the three teachers become more satisfied with learning activities in the CTM. Additionally, teachers' development of how to integrate knowledge bases was evident when comparing their initial lesson plans to inquiry-based lesson plans that were created during CTM III and their microteaching. In CTM III, for Malai and Sirod's first inquiry-based lesson plan of plants and electricity, it consisted of learning objectives, concept topics, learning activity, instructional materials, and assessment and evaluation. Emphatically, these components were explained and there were interrelationships between these components. For Napaporn, her first lesson plan had an inconsistency of learning objectives and assessment method. She articulated her teaching goal that students should be able to draw a picture about the concept of the Earths' atmosphere, but in the learning assessment, Napaporn did not assess that aspect of students' learning. After CTM conducted microteaching, Napaporn changed and improved her second lesson plan that was more detailed and included: learning outcomes, learning activities sequence, instruction media, and assessment methods.

Reflection on Teaching Influenced Teacher's PCK Development

Through the CTM, the result from cross case analysis revealed that Malai, Napaporn and Sirod had many chances to reflect on their own co- teaching, and the others co-teaching. Sirod and Malai indicated that they had learned from participating in the reflection activity, and especially in critiquing the strengths and weaknesses of their own and others' teaching. Like Napaporn's opinion, she additionally pointed out that reflection in CTM was the best way that promoted co-teachers to learn new knowledge and improve their teaching. As CTM progressed, the three teachers agreed that reflection on co-teaching helped them to become aware of the importance of each knowledge base for teaching. They learned classroom management, teaching strategies, techniques for probing student prior knowledge, instructional media, and assessment methods through CTM. The teacher demonstrated that reflection on their own co-teaching helped them understand the strengths and weaknesses of their teaching, and this was useful in developing their PCK.

The Factors that Constrain or Support the Elementary Science Teachers' Understandings and Practices of Pedagogical Content Knowledge through a Co-Teaching Model.

As co-teaching is an increasingly popular teaching approach that provides support to students in diverse inclusive classroom. It is a new strategy in Thai educational context; many teachers are taking the plunge and entering this professional partnership by trial and error. The result from cross case analysis revealed that the success of co-teaching rested upon six supporting factors presented in the following paragraphs.

The first factor was that both partners can blend their instructional expertise and interpersonal skills. These were the main factors that helped the co-teachers success with their co-teaching. As the characteristics of co-teaching that were mentioned in previous topics, if the co-teachers could display parity and mutual respect, agree on specific mutual goals, and share accountability for outcomes and resources, they would have successful teaching. Particularly, these components were more likely to occur within a school climate that emphasized collaborative relationships therefore the second factor was that the school principal should be one of the CTM team and understand the process of co-teaching very well. Furthermore, as in any relationship, co-teachers grew and became more comfortable with each other, the students, and their responsibilities over time.

The relationship among Malai, Napaporn and Sirod was identified in three stages when they began to participate in CTM. The three teachers in the beginning stage were hesitant to make independent decisions due to their unfamiliarity with each other, and their interpersonal relationship appeared somewhat awkward. After they had worked together for three weeks, they changed their relationships to the compromising stage that was more comfortable with each other and their instructional responsibilities, and often they used the "my turn, your turn" approach. At the end, the teachers experienced a high level of comfort with each other and the curriculum, their instruction was blended and fluid as in the collaborative stage. The third factor then is time for implementing CTM as a crucial factor to support co-teaching. CTM teacher should have more time to participate and learn among members. Knowing and working time for CTM members was the supporting factor for co-teaching model. The forth factor was related to the co-teaching stages (co-planning, co-teaching and co-evaluating), reflecting upon and evaluating the co-teaching experience were a significant process that was integrated into CTM. Napaporn stated that sharing, discussing and reflecting processes that happened in CTM could help her know what she needed to change and how to do it. Like Malai and Sirod reflections, the results were similar for Napaporn. The fifth factor is that the co-teacher should have an opportunity to share his/her idea in CTM meeting. Moreover, the results from the three cases presented that a model for co-teaching reflected these critical components by including each teacher's interpersonal skills, content knowledge, philosophy of teaching, teaching behaviors, and stage in the co-teaching experience. Consequently, co-teachers could integrate these components so that they stay clearly centered on the learning achievement of each student, which was the barometer of success of the co-teaching endeavor.

The sixth factor was about co-planning, co-teaching models, differentiation, universal design, and cooperative learning. Co-teachers should be offered the needed resources; and state department personnel, faculty of institutions of higher education, and personnel from school districts to form partnerships. Further, this study noted that administrators could support co-teaching by publicly articulating the rationale for co-teaching, redefining teachers' roles, assessing the teacher' s need for co-teaching, creating a master schedule that allows for co-teaching, and educating others about the accomplishments of co- planning and teaching teams. Administrators could also provide access for both teachers to student files, grading programs, and other student information that was critical for instructional purposes.

Not only high level people were involved in co-teaching model, student perspective was also an important factor that affected the co-teaching classroom. Sirod pointed out that the co-teacher should consider "Had the student needs-rather than the co-teaching model-dictated students? Had co-teacher considered student needs and preferences when assigning students to the co-taught classroom? Had co-teacher prepared all students for the co-teaching approach? Malai also was conscious that just as most adults appreciate being prepared for and involved with change, students also appreciate being involved in changes that affect them.

For seven supporting factors that were discussed as above, they could become constraining factors if the professional development programmed using co-teaching failed to acknowledge or implement them. After the CTM was implemented, the result from cross case analysis revealed that personal characteristics of the co-teacher also could influence whether the programmed will be a success or a failure in improving teaching and learning science. Malai commented that before participating in CTM, a teacher should answer the question, “Are you really ready or prepared to co-teach? Do you have the personal characteristics that enable you to work well with another teacher in a shared space? Can you provide a safe learning environment not only for students but also for your co-teacher? Are you willing to share your classroom and materials with someone else? What are you willing to give up co-teaching? Willingness and readiness for co-teaching were the main constrain factors if the co-teacher were not forthcoming.

For two semesters that Malai, Napaporn and Sirod worked as co- teachers in CTM, the result from cross case analysis indicated that they had not enough time for participation in the CTM because of their workload from their schools. In addition, Malai, Napaporn and Sirod agreed that they needed more time to get to know and be familiar with the teacher who would work as their co-teacher. Napaporn stated that co-teaching was first and foremost a relationship. Like any relationship, co-teaching moved though stages, from the first “getting to know “stage to the final “thinking as one” stage. The relationship of co-teachers developed they got to know each other, built trust and common repertoire, and worked toward the final goal of co-teaching. Sirod illustrated that as in any relationship, teachers would experience different starting points and different timetables. Sometimes teachers volunteered to co-teach together. In that situation, the relationship probably started long before the co-teaching experience, even though that relationship may only have been social. At the other extreme, co-teachers with only a nodding acquaintance, if any, may be assigned to teach together. In this situation, the teachers must build their relationship from scratch. Consistent with Gately and Gately (2001) identified three stages of co-teaching: beginning, compromising, and collaborating. Co-teachers with a limited work relationship prior to the co-teaching experience would start at the beginning stage and probably progress through the stages more slowly than teachers with a previously established relationship. This was to be expected to understand the developmental progression of co-teaching and accept the realities and challenges of each stage. Malai and Napaporn knew each other more than ten years therefore their relationship in co-teaching progressed expeditiously. Unlike when Sirod who co-taught with Napaporn or Malai; Sirod was a new teacher in the science department. At the first meeting of CTM, he revealed that he was self-conscious to talk with either Malai or Napaporn.

In summary, this chapter presented frequently noted characteristics of the pedagogical content knowledge developed by elementary science teachers when engaged with the co-teaching model. It described the characteristics of a co-teaching model designed to facilitate elementary science teachers' development of pedagogical content knowledge; and identified the factors that support (or through their absence could constrain) elementary science teachers while implementing with the co-teaching model. After the CTM experience, the three teachers developed their knowledge of science, pedagogy, and context. There were many things that happened during the CTM. However, CTM experience suggested that co-teachers should considering ways to share their instructional expertise; sharing their visions for the co-teaching experience; committing them to focusing on students' needs; communicating ways in which they would emphasize personal integrity; and scheduling a regular time to reflect on their co-teaching practice.

CHAPTER VI

CONCLUSIONS AND IMPLICATIONS

Introduction

This chapter aims to provide the conclusions and implications of the research study. The chapter begins with a summary of the study. It is followed by the conclusions of the research results. The chapter is ultimately completed with the implications of this study for the educational community.

Research Summary

Research Aims

The present study is about elementary science teachers who participated in the teacher professional development program, entitled the co-teaching model [CTM] in the academic year 2009. The research study involved three teachers, Ms. Malai, Ms. Napaporn, and Mr. Sirod and analyzed their efforts to develop their professional knowledge in PCK and to make changes in implementing inquiry-based teaching and learning in their science classrooms. The three teachers' understandings and practices regarding PCK were presented both before and after the teachers participated in the CTM. The study also considered efficacy of utilizing the CTM in promoting the teacher's understanding and practice of inquiry-based teaching and learning in a real classroom context.

Research Questions

This study is shaped by the following research questions:

Research Question 1

1. What are the understandings and practices of elementary science teachers' pedagogical content knowledge [PCK] prior to participating in the Co-Teaching Model [CTM]?

1.1 What are teachers' understandings and practices about subject matter knowledge?

1.2 What are teachers' understandings and practices about pedagogical knowledge?

1.3 What are teachers' understandings and practices about knowledge of context?

Research Question 2

2. What were the characteristics of a CTM that appeared to be the most effective in bringing about changes in the teachers' PCK?

Research Question 3

3. What are some of the characteristics of the PCK developed by elementary science teachers when engaging with the CTM?

3.1 Do any changes occur in the teachers' understandings and practices about subject matter knowledge?

3.2 Do any changes occur in the teachers' understandings and practices about pedagogical knowledge?

3.3 Do any changes occur in the teachers' understandings and practices about knowledge of context?

Research Question 4

4. What do factors constrain or support the elementary science teachers' implementation of the CTM?

Conclusions of the Study

This section presents the conclusions of the research study, which are divided into four parts according to the four research questions:

Conclusions in Relation to the First Research Question

The first research question was about what elementary science teachers' understanding and practice of PCK before participating in CTM. To address the first research question, PCK was considered in aspects of subject matter knowledge, pedagogical knowledge and knowledge context. There were multiple sources of data that were gathered including individual interview, card sorting, classroom observations, inquiry-based lesson plans, written reflections, and central meetings. All of the data sources were collected during the CTM I-II of the study. The findings across the three case studies reveal that before the professional development experiences, the three teachers did not a full understanding and practice of PCK. Three teachers realized that they should teach science based on student-directed inquiry in their science classrooms. In general, the teachers knew their role and their students' role in inquiry-based teaching and learning consistent with the NSCS. For the goals and purpose for teaching science, the three teachers did not focus their inquiry-based lessons on scientific attitudes. The teachers focused their lessons only on scientific knowledge and science process skills. Their initial understanding of PCK in aspects of subject matter knowledge, pedagogical knowledge, and knowledge of context were somewhat based on constructivism. However, their practices of PCK did not agree with their understanding. Particularly, the teachers were not confident in science knowledge. Most of problems that were articulated by the teachers came from their lack of science knowledge. They had problems with their knowledge of science content because they did not have a science education background. Their initial lessons focused on students' learning science content and science process skills as the major teaching and learning goals. However, they also stated that students should learn scientific attitudes as minor goals. In addition, the teachers also stated that student understanding of the nature of science should be a learning goal. Some aspects of the teachers' practices were aligned with their beliefs; however, they still conducted their classroom using a teacher-centered approach.

The three teachers' initial PCK knowledge base was limited. Even though their understanding and practices of PCK for teaching and learning science were constructivist in nature, their knowledge of student learning and teaching strategies were based on positivist understandings of science content. They rarely focused on prior knowledge and learning, and most learning activities were based on lectures. Initially, they were frustrated with the ideas of student-centered teaching. In the CTM I, the teachers' understandings and practices regarding pedagogical knowledge were aligned with teacher-directed inquiry. The teachers' understandings and practices reflected a combination between the notions of confirmation activities (Bell, 2002) and structured inquiry (Colburn, 2000; DCID, 2002). The three teachers conducted their initial lessons through confirmation activities that were referred to as a teacher-directed type of inquiry where the teachers provided questions, step by step procedures, and materials for learners. Learners were involved in activities in an effort to rediscover some identified phenomena. Some classes were taught by structured inquiry. They provided a question, hands-on investigation, and materials for learners. Students sometimes were provided chances to think logically, to select a method for recording data, and to analyze data. The findings across the three teachers indicated that normally the students learned the science concepts from textbooks or teachers' explanations before doing investigations. The investigations were used for rediscovering or verifying identified concepts. In their intended instructional practices, the teachers stated that students should learn science through hands-on investigations and they should be responsible for analyzing data and making conclusions. However in practice; the investigations were devised only by the teachers. They formulated conclusions for students or had students make conclusions on their own without sharing their conclusions with others. Although the students were clustered into groups and provided the opportunity to learn as a group, often the group members did not work cooperatively. For other aspects of knowledge in PCK, the cross case analysis illustrated that teachers' knowledge of assessment centered on conceptual knowledge and heavily emphasized non-specific assessment methods. They especially paid more attention to paper-pencil tests and worksheets for evaluating students' learning at the end of a course. They mainly used the Science Curriculum Framework as teaching and learning resource. When comparing the teachers' espoused understanding with their practices, the findings indicated that the teachers' instructional practice was somewhat different from their beliefs. For the role of the teacher, the three teachers played more roles than they thought they played. The three teachers understood that they should implement their teaching and learning science based on educational reform. However, they abandoned it because they did not have colleagues to consult and discuss with.

Conclusions in Relation to the Second Research Question

The second research question was articulated to understand the efficient characteristics of a co-teaching model designed to facilitate elementary science teachers' development of pedagogical content knowledge. To address this question, multiple sources of data were used to establish the results of the study. The data sources included individual interviews, card sorting, classroom observations, written reflections, and central meetings. The data was collected during the four phases of the CTM: CTM I- IV. The findings from cross-case analysis presents the characteristics of the co-teaching model designed to facilitate elementary science teachers' development of their PCK during the two semesters that the elementary science teachers and the researcher worked together and shared their experiences and knowledge. The analysis indicated that important characteristics for the success of the CTM requires the participants to attend to the following issues: the parity between the participants, mutual respect, specific mutual goals, shared accountability for outcomes, shared resources, school climate and time, administrative support, parent support and student's perspective of co-teaching model. Consequently, an effective CTM should be based on the activities that provided opportunities for co-teachers to get to know each other. Collaborative relationships were important for the CTM team. In this study, the CTM consisted of three stages: co-planning, co-teaching, and co-evaluating. However, the three teachers also were provided the opportunity to meet each other in the first central meeting. The teachers should have a chance to develop collegial relationships before they become involved in the CTM experience. In addition, the teachers should be encouraged through activities that helped them clarify their understanding of teaching and learning goals. In the planning stage, CTM was successful when the teachers had time to work together. Making a proper schedule for co-teachers in the planning stage was the main strategy for enhancing teachers' development of PCK. Finding time for collaboration in the planning stage should be considered as the main characteristic of co-teaching because co-teachers should have time to share, discuss, and reflect on their understanding that brought them to change their instructional practice. Consequently they would not struggle when they applied their understanding into practice. The teachers expressed their concern about the time needed to form collaborative working relationships with their colleagues particularly for activities such as co-planning. Co-teaching is best accomplished when people literally put their brains together, in face to face meetings. The study revealed that a structured meeting format would be both effective and efficient when used, such as the co-teaching central meeting agenda. The aspect of positive inter-dependence is clarified as the structure that distributes leadership among group members by assigning and rotating roles. Roles may be task-related or relationship-oriented. An effective CTM should incorporate a flexible meeting agenda that is comfortable for CTM members. The CTM activities should enable the co-teachers to understand their roles and responsibilities during co-teaching and co-evaluating. As the characteristics of CTM mentioned earlier, if the CTM can be build on these features, CTM team will more likely be successful in their efforts.

Conclusions in Relation to the Third Research Question

The third research question studied the characteristics of PCK developed by elementary science teachers when participating in the CTM. To address this question, multiple sources of data were used to establish the results of the study. The data sources included individual interviews, card sorting, classroom observations, inquiry-based lesson plans, written reflections, and central meetings. The data was collected during the last three phases of the CTM [CTM II-IV]. As the CTM progressed, the result from cross case analysis revealed that the three teachers' PCK gradually progressed through the learning activities in the CTM. The teachers were provided with many opportunities to broaden their understanding and practices about the nature, teaching and learning of science. They had a chance to express their initial understandings and compare their understandings to constructivist understandings of teaching and learning science, proposed in the Basic Education Curriculum, and the Science Curriculum Framework. In co-planning, co-teaching, and co-evaluating stages, the teachers worked with colleagues collaboratively. They increasingly integrated their understanding and practice of PCK in aspects of subject matter knowledge, pedagogical knowledge, and knowledge of context through sharing, reflecting, and discussion during their co-planning, co-teaching, and co-evaluating. Through these activities, the teachers' understanding and practices of PCK supported teaching and learning science based on constructivism shifted to more constructivist understandings specifically, in the nature of scientific knowledge. Their understanding of science curriculum was influenced by analyzing and discussing the science curriculum framework, and from the reflection with the CTM team about school-based science curriculum. When they were asked to analyze the Science Curriculum Framework, discuss and reflect their ideas with the CTM members about school-based curriculum development, they came to understand more about the goals of teaching and learning science, learning standards, the school-based curriculum, basic science and advanced science. Additionally, making observations of the co-teacher's teaching and discussion of student prior knowledge and learning enhanced the teachers' awareness of the importance of student prior knowledge and individual differences in learning. They learned that the students held different science conceptions. Sharing, reflecting, and discussing during co-planning, co-teaching, and co-evaluating of CTM are key activities in the CTM that enhanced their PCK development. Through participating in the CTM, Malai, Napaporn, and Sirod increased their understanding about student-centered learning. After the co-planning stage, teachers' lesson plans were consistent with their learning goals and purposes. Their learning activities, the use of instruction media, and assessment methods were more detailed and were more interrelated. They appeared focused more on teaching science by inquiry approach and enhanced students to learn science by group learning as one dimension of student learning; based on the School-based Curriculum and the

Science Curriculum Framework. Lesson plan' development; used a variety of assessment methods such as asking questions of students, observing their behaviour, and interacting with them. Moreover, the teachers also brought school and community contexts into their instructional practices. These student-student and student-teacher interactions appeared in their microteaching activity. When they brought their understanding of PCK into teaching practice with the co-teacher it revealed that three case studies had greater development in the understanding and practice of PCK for constructivist teaching and learning. The results of the three case study teachers indicated that after receiving the professional development experiences, they had better understandings and practices of PCK that supported them to be more confident in integrating of subject matter knowledge, pedagogical knowledge and knowledge of context for their classroom practices. The teachers expanded their understanding and practice about inquiry-based teaching and learning more than their initial notions and existing practices. In particular, the teachers' understandings and practices after participating in the CTM reflected a shift toward a more learner-directed type of inquiry. The three teachers held full understandings and practices about student-directed inquiry in terms of the teaching strategy: lesson introduction, investigation, conclusion/explanation, communication, and group working.

As the CTM progressed, the three teachers gradually accepted their multiple roles and the student's role as an active and minds-on investigator. They realized that they needed to emphasize in their inquiry-based lessons the three elements of scientific knowledge, science process skills, and scientific attitudes as goals and purposes for teaching science. With regard to instructional process, the teachers' understandings and practices moved forward mainly from the notions of structured inquiry and guided inquiry to open inquiry (Colburn, 2000: DCID, 2002). The teachers implemented their co-teaching lessons through opened-inquiry was consistent with Colburn (2000) who suggested that open inquiry had similarities with guided inquiry. The addition was that in this type of inquiry, learners formulated their own problem or question to investigate. The teacher acted as a facilitator who provided learners with materials as needed. In their initial practice the teachers conducted their inquiry-based teaching and learning that was consistent with the

DCID (2002), who recommended structured inquiry where the teacher provided questions, hands-on investigations, and materials for learners. After CTM II-IV the teachers encouraged the learners to devise their own investigation to address the question -- a type of guided inquiry. The teachers subsequently developed more open-ended inquiry-based lesson plans providing students opportunities to do small science project.

Malai, Napaporn, and Sirod changed their understanding of PCK in that they became more confident in their science knowledge, integrating guided and open inquiry approach, and utilized school and community contexts for lesson development. In the co-teaching stage, the results from three cross case analysis indicated that their practices became more aligned with their understanding. With regard to the instructional process, their students were encouraged to think, do Hand-on activity, be challenged to apply science knowledge into their daily lives. The first implementation of the teachers' lesson plan, students conducted an investigation to answer the questions that were provided by the teachers. However, in the last three lesson plans, students were encouraged to do investigations/experiments following the students' interest. Napaporn and Malai also provided time for students to do science projects. Sirod, however, focused more on students' searching information based on their interests. After each co-teaching session, the co-teachers discussed and reflected on their co-teaching. The three teachers became more aware of the multiple roles of teaching. The roles included guide, motivator, facilitator, and activity director. The three teachers motivated the students to learn science as active and minds-on investigators. All of the teachers focused their inquiry-based lessons on scientific knowledge, science process skills, and scientific attitudes consistent with the NSCS. At the end of their lessons, the three teachers incessantly connected new knowledge with students' prior knowledge.

CTM provided experience for Malai, Napaporn, and Sirod to work together in planning, teaching, and evaluating. The process of sharing, discussing, and reflecting about their understanding and practice of PCK awakened the three teachers to move on their understanding and practice of PCK to be consistent with learner-centered approach. Developing science knowledge, pedagogical knowledge, and knowledge of content of three teachers was gradually developing along with CTM proceeding.

Conclusions in Relation to the Fourth Research Question

The fourth research question was about the factors that constrain or support elementary science teachers' development of PCK during the CTM process. To answer this question, multiple sources of data were used to establish the results of the study. The data sources included individual interviews, card sorting, classroom observations, inquiry-based lesson plans, written reflections, and central meetings. The data was collected during the three phases of the CTM: CTM II- IV.

The finding from cross-case analysis suggests that successful CTM has to be based on teachers' personal characteristics such as: that the co-teachers are prepared to co-teach, that they can blend their instructional expertise and interpersonal skills, that they show mutual respect for each other, that they can agree on specific mutual goals, and that they can share accountability for outcomes and resources. More than just the teachers' personal characteristics, a school climate is important to influence co-teachers spending time to work collaboratively. Collaborative relationships are a key aspect of a successful CTM program and therefore, the school leader should understand how the CTM team works.

Further, as in any relationship, co-teachers grew and became more comfortable with each other, the students, and their responsibilities over time. For two semesters in CTM implementing, it reveals that providing time could be both supporting and constraining factor for the three teachers when they engaged within CTM. The three teachers spent time to learn and work with each other. At the beginning stage, they used the "my turn, your turn" approach. Finally, the teachers worked together as in the collaborative stage. In addition, the CTM processes included sharing, discussing and reflecting on each teacher's interpersonal skills, content knowledge, philosophy of teaching, teaching behaviors, and stage in the co-teaching experience should be clarified clearly centered on the learning achievement of each student, which was the barometer of success of the co-teaching endeavor.

Supporting and respectful administration is an important factor that facilitated Malai, Napaporn, and Sirod to have a positive CTM experience and develop their PCK. Successful change depends on administrators acting as a professional partner who is willing to support innovative ideas in teaching. When the teachers would like to participate with CTM, their school principal gave them the green light to spend time, share classrooms, and have meetings at the school. The principal extended to them the emotional and financial support they needed to be successful, he respected them as educators who knew what was best for their students. Not only support from the school principal, student perspective should be considered as factors for the CTM.

There were many factors that could support and constrain Malai, Napaporn, and Sirod to develop their PCK through CTM. For the study, the three teachers had very strong personal characteristics in volunteering their classrooms. The CTM was implemented equably. The factor of time seems to be the major constraint for this research because the three teachers still had full workloads from their school. In addition, Malai, Napaporn and Sirod agreed that they needed more time in getting to know and be familiar with the teacher who worked as their co-teacher. The CTM should rest on a flexible schedule that is propitious for the co-teachers. The obstacles and facilitating factors should be considered before taking the plunge to use co-teaching because CTM does not occur in a vacuum, and successful co-teaching does not occur overnight. Teacher’s willingness and readiness in CTM participation are considered as device drivers.

Implications of the Study

This section provides the implications of the research study. The implications are presented in relation to professional development, science teaching and learning the co-teaching model, research methodology, and further studies.

Implications for Professional Development

The professional development program utilized in this study involved the use of basic elements of co-planning, co-teaching, and co-evaluating to promote the teachers' understandings and practices of PCK for a reformed science classroom. They can implement their knowledge as theory into their actual practice in real classrooms. According to the results of this study, the CTM is productive in affecting changes of the case study teachers' understandings and practice of PCK in the classroom. The crucial components underlining the CTM that are likely to have an impact on the development of the science teachers might be: establishing common goals among program members, empowering teachers' leadership of the professional development program, providing opportunities for teachers to learn in their actual classrooms, giving time and support for teachers to plan, implement, observe, and reflect on their lessons, providing chances for teachers to learn through other teachers who are colleagues, having long-term assistance for continuous learning and practical change, and most importantly building and sustaining a trusting and respectful atmosphere among the teachers and the researcher. In summary the results from this research has discovered an important way for the creation of professional teacher development in science. Professional development should be created by teachers' needs and their problems regarding teaching science in real situations. The professional development program should help elementary science teachers in integrating all elements of knowledge; how to integrate content knowledge, teaching knowledge, including setting goals for teaching science, methods of teaching science, learners and learning, curriculum and assessment and evaluation. The development of targeted science teacher's knowledge should look to develop long-term collaborative working. The collaborative works in all three stages of the co-teaching model are effective opportunities for exchanging teachers' understanding of each aspect in PCK. The teachers can then apply their understanding into practices properly. Opinions and experiences of individual teachers must be relevant to the needs of the teacher professional development program. In the study, there are three stages of CTM: co-planning, co-teaching, and co-evaluating. The three teachers said the most effective stages that helped them change their understanding and practice of PCK were the co-planning and co-evaluating stages. Future professional development programs regarding the co-teaching model should consider integrating these two stages as major strategies for developing teacher knowledge and their practices. Particularly, in the context of time limit, the co-teaching model should focus on providing the opportunity for teachers to share, reflect, and discuss their understanding and practice of PCK.

Implications for Teaching Science through Integrating PCK

The results of CTM study suggest several aspects need to be addressed for science teachers to be successful in integrating PCK in their teaching of science, particularly in a classroom similar to the case study teachers'. First, the science teacher needs to hold the goals and purposes that focus on student learning with respect to science knowledge, science process skills, and scientific attitude. The students should be encouraged to learn science based on the three aspects; science knowledge, science process skills, and scientific attitude, they can teach science along with the reform-based science teaching. Second, strong subject matter knowledge would make it easier for the science teacher to teach science through inquiry-based teaching and learning. In this case study, the three teachers agreed that in teaching science via CTM they tended to choose science concepts that they were less knowledgeable about. They revealed that they would like to have a team that helped them to design their lesson plans, suggest to them teaching approaches, and share science knowledge with difficult concepts. In the past, the science concepts that the three teachers had difficulty understanding resulted in reduced learning for the students. Third, the students should be taught science by inquiry approach. The elementary science teachers should initially use a teacher-directed level of inquiry to the students who have different backgrounds. The lessons can begin with more teacher-directed level of inquiry (guided inquiry) to less teacher-directed level of inquiry (open inquiry). Students should be provided time and support by teachers to have experience and be familiar with the inquiry approach. Fourth, the science teachers have built a good relationship with students. Teachers who have a good relationship with students are more likely to have students' cooperation when experimenting with new pedagogical approaches. Fifth, interesting activities and effective questioning are needed for stimulating students' curiosity. Blending students' daily lives into the Hand-on activity is propitious strategy to motivate student learning. Last science teaching and learning should refer to school and community context as learning resources. The results of this study showed that elementary science teachers are more confident to teach following inquiry-based lesson plans when they have a team to work and discuss with. The teachers experienced difficulty in teaching science based on reformed science education because they did not have strong science knowledge and their understanding of the goals and purposes for teaching science was restricted to science knowledge and science process skills. To solve this problem the teachers should have a chance to work collaboratively with colleagues starting from co-planning stage until the co-evaluating stage. The CTM can be adjusted depending on school context.

Implications for Methodology

The implication from this study is the importance of developing methods and approaches which permit researchers to obtain a better understanding of teachers' PCK. Science teachers were chosen initially based on the criterion that they taught science at the elementary level in the same public school. The teachers were then selected by considering three other criteria: they volunteered to participate in the CTM, their lack of opportunity to engage in any professional development programs/workshops related to PCK during the past five years, and they teach science subject in grade four, five and six in the same school. This sampling method enabled the researcher to learn and gain a profound understanding of the teachers' understanding and practice through the use of case study methods (Patton, 2001). One additional assumption guiding teacher selection was that science teachers from similar contexts or one school might be able to understand issues confronted in classrooms, provide suggestions, and learn from each other better than those who came from diverse circumstances.

The data analysis of this study includes within-case and cross-case analyses. Once the data is analyzed, the findings are reported via thick description. This presentation method is also recognized as a powerful way to provide readers a better understanding of each individual case when compared with presenting the results using abstract theories or principles. In this regard, both results and contexts surrounding each teacher are presented. The readers are invited to reinterpret or create their own stories about the teachers' understandings and practices in relation to PCK.

For two semesters at the beginning of this study, the researcher attempted to immerse herself into the field. During the first month of the study, the researcher frequently met the teachers in their schools, visited the teachers' classrooms, and talked informally with the teachers and students. These school visits were intended to build up a trusting, respectful, and familiar personal relationship between the researcher and teachers, as well as to familiarize the researcher with the teachers' contexts. The researcher believes that the friendly relationship among CTM members was a major factor that she received the teachers' cooperation in the CTM. This study reinforces the importance of the researcher immerse him/herself in the field so as to build up a positive atmosphere and relationships with the research participants before he/she continues to the next step of the research agenda.

Implications and Recommendations for Further Study

The results of this study indicate that participation in CTM was a successful strategy for promoting changes in science teachers' understandings and practices of PCK from a teacher-directed to learner-directed set of instructional practices. They were at the end of the project able to integrate all aspects of knowledge or PCK in their practices. However, the study did not investigate the process that individual teachers used to change their understanding and practice of PCK. Thus, this study suggests that there is value in future research, particularly in a Thai context, to study how science teachers learn to change their understandings and practices of PCK in the context of a professional development model similar with the CTM. There is also the need for future study to investigate how science teachers maintain their new understandings and practices of PCK during or after they leave the professional development program.

For readers and researchers who are interested in doing similar studies, it is important to remember that this study was conducted with a group of three science teachers who taught at the elementary level in the same school. The findings from this study were not intended to generalize to all science teachers. Nevertheless, the description of how the CTM approach to professional development was implemented and the context surrounding the use of this approach may be useful to others who decide to use this as model for teacher professional development in their own context.

REFERENCES

Adler, P. A. and P. Alder. 1994. "Observational Techniques." In N.K. Denzin and Y.S. Lincoln. (eds.). **Handbook of Qualitative Research**. Thousand Oaks, CA: Sage, 377-392.

Ball, D. L. and H. Bass. 2000. "Interweaving Content and Pedagogy in Teaching and Learning to Teach: Knowing and Using Mathematics." In J. Boaler. (ed.). **Multiple Perspectives on the Teaching and Learning of Mathematics**. Westport, CT: Ablex, 83–104.

Baxter, J. and N. Lederman. 1999. "Assessment and Measurement of Pedagogical Content Knowledge." In J. Gess-Newsome and N. Lederman. (eds.). **Examining Pedagogical Content Knowledge: The Construct and Its Implications for Science Education**. The Netherlands: Kluwer Academic Publishers, 95-132.

Becker, H. S. 1998. **Tricks of the Trade: How to Think about Your Research while You're Doing It.** Chicago: University of Chicago Press.

Borko, H. and R. Putnum. 1996. "Learning to Teach." In D.C. Berliner and R.C. Calfee. (eds.). **Handbook of Educational Psychology.** New York: Macmillian, 673-708.

Bromme, R. 1995. "What exactly is Pedagogical Content Knowledge? Critical Remarks Regarding a Fruitful Research Program." In S. Hopmann and K. Riquarts. (eds.). **Didaktik and/or Curriculum** 147: 205-216.

Brown, G. 1997. **Assessing Student Learning in Higher Education**. London: Routledge.

Brown, S. and P. Knight. 1994. **Assessing Learners in Higher Education**. London: Kogan Page.

Candy, P. 1989. "Alternative Paradigms in Educational Research**.**" **Australian Educational Researcher** 16 (3):1-11.

Carsen, W. S. 1991. "Effects of New Biology Teachers' Subject-Matter Knowledge on Curricular Planning." **Science Education**. 7 (5): 31-53.

Carter, K. 1990. "Teachers' Knowledge and Learning to Teach." In W.R. Houston. (ed.). **Handbook of Research on Teaching**. New York: Macmillan, 255-296.

Clandinin, J. 1985. "Personal Practical Knowledge: A Study of Teachers' Classroom Images." **Curriculum Inquiry** 15 (4): 361-385.

Clotfelter, C. T., H. F. Ladd, and J. L. Vigdor. 2007. "Teacher Credentials and Student Achievement: Longitudinal Analysis with Student Fixed Effects." **Economic of Education Review** 26: 673-682.

Cochran, K. F. 1992. "Pedagogical Content Knowledge: Teachers' Transformations of Subject Matter." **Manhattan, KS: National Association for Research in Science Teaching**.

______. 1997. "Pedagogical Content Knowledge: Teachers' Integration of Subject Matter, Pedagogy, Students, and Learning Environments." **Research Matters - to the Science Teacher.**

Cochran, K. F., J. A. DeRuiter., and R. A. King. 1993. "Pedagogical Content Knowledge: An Integrative Model for Teacher Preparation." **Journal of Teacher Education** 44, 263–272.

Collingwood, R. G. 1961. **The Idea of History**. Oxford: Clarendon.

Connole, H., B. Smith, and R. Wiseman. 1993. **Issues and Methods in Research: Study Guide.** Adelaids: University of South Australia.

Crawford, B. A. 2000. “Embracing the Essence of Inquiry: New Roles for Science Teachers.” **Journal of Research in Science Teaching** 37 (9): 916-937.

Creswell, J. 1998. **Qualitative and Research Design: Choosing among Five Traditions**. Thousand Oaks, California: Sage Publications.

______. 2003. **Research Design: Qualitative, Quantitative, and Mixed Methods Approaches**. Thousand Oaks, California: Sage Publications.

Croninger, R. G. *et al*. 2007. “Teacher Qualifications and Early Learning: Effects of Certification Degree, and Experience on First-Grade Student Achievement.” **Economics of Education Review** 26: 312-324.

Davis, E. A. 2003. “Prompting Middle School Science Students for Productive Reflection: Generic and Directed Prompts.” **The Journal of the Learning Sciences** 12 (1): 91–142.

Dilthey, W. 1958. **Gesammelte Schriften**. B.G. Teubner.

Donoghue, T. O. 2007. **Planning Your Qualitative Research Project: An Introduction to Interpretivist Research in Education.** New York, NY: Routledge.

Doyle, W. 1990. “Handbook of Research on Teacher Education Research.” In W. R. Houston, M. Haberman and J. Sikula. (eds.). **Handbook of Research on Teacher Education**. New York: Macmillian.

Dufour, R., R. Eaker, and R. DuFour. 2005. **On Common Ground: The Power of Professional Learning Communities**. Bloomington, Ind.: National Educational Dervice.

Duit, R. 2007. **Bibliography STCSE—Students' and Teachers' Conceptions and Science Education** (Online). www.ipn.unikiel.de/aktuell/stcse// bibint.html, June 25, 2007.

Emer, M. 1986. **Qualitative Research.** Canberra: Australian Association for Adult Education.

Foreign Office the Government Public Relations Department. 2007. **Inside Thailand review: Sufficiency Economy and Social Integrity**. Bangkok. Thailand.

Friend, M. and L. Cook. 2007. **Interactions: Collaboration Skills for School Professionals.** 5 th Ed.. Boston: Peason Education.

Fullan, M. 1982. **The Meaning of Educational Change.** NY: Teachers College, Columbia University.

Gall, M. D., W. R. Borg, and J. P. Gall. 1996**. Educational Research an Introduction**. USA: Longman Publication.

Gately, S. and F. Gately. 1999. "Understanding Co-teaching Components." **Journal of Teaching Exceptional Children** 2 (3): 41-47.

Geddis, A. N. 1993. "Transforming Subject-Matter Knowledge: the Role of Pedagogical Content Knowledge in Learning to Reflect on Teaching." **International Journal of Science Education** 15 (6): 673-683.

Gimbert, B. 2007. "The Influence of Teacher Preparation on Student Achievement and the Application of National Standards by Teachers of Mathematics in Urban Secondary Schools." **Education and Urban Society** 40 (1): 91-117.

Glaser, B. G. and A. L. Strauss. 1967. **The Discovery of Grounded Theory**. New York: Aldine.

Goetz, J. and M. Le Compte. 1984**. Ethnography and Qualitative Design in Education Research**. Orlando, FL: Academic Press.

Green, J. L., G. Camilli, and P.B. Elmore. 2006. **Complementary Methods in Education Research.** Washington, D.C.: Lawrence Erlbaum Associates, Inc.

Grimmett, P. and A. Mackinon. 1992. "Craft Knowledge and the Education of Teachers." In G. Grant. (ed.). **Review of Research in Education**. Washington, DC: American Educational Research Association.

Grossman, P. 1990. **The Making of a Teacher: Teacher Knowledge and Teacher Education**. New York, Macmillan.

Grossman, P. L. 1990. "Values in Pedagogical Content Knowledge." **Journal of Teacher Education** 41 (3): 44-52.

Guba, E. G. and Y. S. Lincoln. 1981**. Effective evaluation: Improving the Usefulness of Evaluation Results through Responsive and Naturalistic Approaches**. San Francisco: Jossey-Bass.

______. 1989. **Fourth Generation Evaluation**. Newbury Park, California: Sage Publications.

Guba, E. and Y. Lincoin. 1994. “Competing Paradigms in Qualitative Research.” In N. Denzin and Y. Lincoln. (eds). **Handbook of Qualitative Research**. Thousand Oaks, CA: Sage Publications: 530-544.

Gudmundsdottir, S. 1987a. “Learning to Teach Social Studies: Case Studies of Chris and Cathy.” **American Educational Research Associatio**n. Washington, D.C.

______.1987b. “Pedagogical Content Knowledge: Teachers' Ways of Knowing.” **American Educational Research Association**. Washington, D.C.

Hammer, D. 2000. “Student Resources for Learning Introductory Physics.” **American Journal of Physics** 68: 52 – 59.

Hammond, D. 1996. “Teacher Quality and Student Achievement. A Review of State Policy Evidence**.**” **Unpublished Manuscript.**

______. 2000. “Teacher Quality and Student Achievement. A Review of State Policy Evidence.” **Journal of Education Policy Analysis** 8 (1).

Hamza, K. M. and P. O. Wcikman. 2007. “Describing and Analyzing Learning in Action : An Empirical Study of the Importance of Misconceptions in Learning Science.” **Science Education** 92 (1): 141-164.

Institute for Promotion of Teaching Science and Technology [IPST]. 2002a. **National Science Curriculum Standards**. Bangkok: Karusapa Press.

______ . 2002b. **The Manual of Science Learning Management under the Basic Education Curriculum B.E. 2544**. Bangkok: Karusapa.

Jurawatanaton, M. 2003. **The Policy for Producing and Developing Teachers.** Bangkok: The Institute of National Education Committee.

Kelly, J. 2000. "Rethinking the Elementary Science Method Course: A Case for Content, Pedagogy, and Informal Science Education". **International Journal of Science Education** 22 (7): 755-777.

Keawdang, R. 1998. **The binding of Thai Educational Articles in the Years 1997-1998.** Bangkok: The Institute of National Education Committee.

______ . 2002. **Report of Seminar on the Research and Development on Models of School-Based Training Project**. Bangkok: ONEC.

Kross, A. and P. Reiska. 2006. **Research in Science Education—Past, Present, and Future**. Dordrecht: Kluwer.

Leach, J. and P. Scott. 2003. "Individual and Sociocultural Views of Learning in Science Education." **Science and Education** 12: 91 – 113.

Lincoln, Y. S. and E. G. Guba. 1985. **Naturalistic Inquiry**. Beverly Hills, CA: Sage Publication, Inc.

Linn, M. C. and B. S. Eylon. 1996. **Lifelong science learning: A longitudinal case study.** Paper Presented at the Cognitive Science Conference, San Diego, CA.

Loughran, J. J., A. Berry, and P. Mulhall. 2006. **Understanding and Developing Science Teachers' Pedagogical Content Knowledge**. Rotterdam: Sense Publishers.

Loughran, J. J., P. Mulhall, and A. Berry. 2004. "In Search of Pedagogical Content Knowledge in Science: Developing Ways of Articulating and Documenting Professional Practice." **Journal of Research in Science Teaching** 41 (4): 370-391.

______. 2006. **Understanding and Developing Science Teachers' Pedagogical Content Knowledge**. Sense Publishers, Netherlands.

Magnusson, S., J. Krajcik, and H. Borko. 1999. "Nature, Sources, and Development of Pedagogical Content Knowledge for Science Teaching." In J. Gess-Newsome and N.G. Lederman. (eds.). **Examining Pedagogical Content Knowledge: the Construct and Its Implications for Science Education**. Dordrecht: Kluwer, 95-132.

Marks, R. 1990. "Pedagogical Content Knowledge: from a Mathematical Case to a Modified Conception." **Journal of Teacher Education** 41 (3): 3-11.

Matthews, R. M. 1994. **Science Teaching: The Role of History and Philosophy of Science**. Routledge, New York.

Medhi, K. 2003. **The Philosophy of Sufficiency Economy** (Online). http://www. kyotoreview.cseas.kyoto, November 25, 2010.

Merriam, S. B. 1988. **Case Study Research in Education**. San Francisco, CA: Jossey Bass.

Mertens, D. M. 1998. **Research Methods in Education and Psychology: Integrating Diversity with Quantitative and Qualitative Approaches**.

Monk, D. H. 1994. "Subject Area Preparation of Secondary Mathematics and Science Teachers and Student Achievement." **Economics of Education Review** 13 (2): 125-145.

Narot, P. 2004. **A Synthesis of Education Research and Trends of Future Research**. Consulting Report Prepared for Office of the National Education Commission (ONEC). Bangkok: ONEC.

National Economic and Social Development Board [NESDB]. 2002. **The Ninth National Economic and Social Development Plan**. Bangkok: Suksapan Panitch.

National Research Council. 1996. **The National Science Education Standards**. Washington, DC: Brooking Institution.

______ . 2000. **Inquiry and the National Science Education Standards**. Washington, DC: National Academy Press.

Nelson, C., P. A. Treichler, and L. Grossberg. 1992. "Cultural Studies: An introduction." In L. Grossberg, C. Nelson, and P.A. Trechler. (eds.). **Cultural Studies** . New York: Routledge.

Novak, J. D. 2002. "Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappropriate Propositional Hierarchies Leading to Empowerment of Learners." **Science Education** 86: 548 – 571.

Office of the Education Council (OEC.). 2004. **Education in Thailand 2004**. Bangkok: Amarin Printing and Publishing Public Company Limited.

______. 2006a. **Report on the Monitoring and Evaluation of Education Reform: Reform of Learning 2005.** Bangkok: 21 Company Limited**.**

______. 2006b. **Report on the Monitoring and Evaluation of Education Reform: Complete 6 years the National Education Act 1999.** Bangkok: 21 Century Company Limited

Office of the Education Council (OEC.). 2006c. **Education in Thailand 2005/2006**. Bangkok: 21 Company Limited

Office of the National Education Commission (ONEC). 1999. **The National Education Act of B.E.** (1999). Bangkok.

______. 2000. **Learning Reform Learner Centered Approach.** Bangkok: ONEC.

______. 2001. **The Research Report for Developing Policy in Thai Science Education Reform**. Bangkok: ONEC.

______. 2001. **The Research Report for Comparing of Educational Reform to Know in Thai Science Education Reform**. Bangkok: ONEC.

______. 2002a. **The National Education Act B.E.2542 (1999) and Amendments (the Second National Education Act B.E. 2545 (2002).** Bangkok: International Relations and Cooperation Center for Educational Reform .

______. 2002b. **National Education Plan B.E. 2002-2016.** Bangkok: Pimdee Co., Ltd.

______. 2006a. **Research Report about Teaching and Learning with Life-long Learning Resources: Zoo.** Bangkok: ONEC.

Osborne, J. and Simon. 1996. Primary Science and Future Directions, Studies in. **Science Education** 26: 99 – 147.

Patton, M. Q. 1987. **How to Use Qualitative Methods in Evaluation**. Newbury Park, CA: Sage.

______. 1990. **Qualitative Evaluation and Research Methods**. 2nd ed. Newbury Park, CA: Sage.

Pellgrino, J. W., N. Chudowsky, and R. Glaser. 2001. **Knowing What Student Know: The Science and Design of Educational Assessment**. Washington, DC: National Academy Press.

Penso, S. 2002. "Pedagogical Content Knowledge: How Do Student Teacher Identify and Describe the Causes of Their Pupils' Learning Difficulties." **Journal of Teacher Education**. 30, 25-37.

Pillay, H. 2002. **Teacher Development for Quality Learning: The Thailand Education Reform Projec**t. Bangkok: ONEC.

Pitiyanuwat, P. 2001. **Reform Proposals for the Teaching Profession in Thailand.** Bangkok: ONEC.

Pongsopon, P., P. Jantrarotai, P. Pantuvisean, and V. Roadrangka. 2003. "Exploring Pre-service Teachers' Biology Content Knowledge." **Kasetsart Journal (Social Science)** 24 (2): 133-144.

Pornsima, A. 2004. **Raijngaan kaan tidtaam Krongkaanfuk-obromkhruu doi chai Rongrian pen Than**. Bangkok: Office of the Education Council (OEC), Ministry of Education.

Roadrangka, V. 2004. **Field Experiences in Science Teacher Preparation Programs in Thailand.** Proceedings of the International Education Conference: "Transforming Teacher Education in the Face of Globalization".

Robinson, W. S. 1951. "The Logical Structure of Analytic Induction." **American Sociological Review** 16: 812-818.

Roth, W. M. and K. Tobin**.** 2002. **At the Elbow of Another: Learning to Teach by** Co-New York: Peter Lang.

Roth, W. M., K. Tobin, C. Carambo, and C. Dolland. 2004. **“**Co-Teaching Resources for Learning and Leaning to Teach Chemistry in Urban Schools.” **Journal of Research in Science Teaching** 41 (9): 882-904.

Schibeci, R. A. and R. L. 2004. “Dimensions of Autonomy: Primary Teachers’ Decisions about Involvement.” **Science Professional Development** 88 (1): 119-145.

Schuster, D. A. and W. S. Carlsen. 2009. Scientists' Teaching Orientations in the Context of Teacher Professional Development. **Paper presented at the Annual Conference of the National Association of Research in Science Teaching**. San Francisco, CA.

Secretariat of the Teacher Council. 1994. **The Seminar on Guidelines for Shifting Teaching Profession Standards**. Bangkok: Secretariat of the Teacher Council.

Shulman, L. 1986. “Those who understand: Knowledge Growth in Teaching.” **Educational Researcher** 15: 4–14.

______. 1986a. **“**Paradigms and Research Programs in the Study of Teaching: A Contemporary Perspective.” In M.C. Wittrock. (ed.). **Handbook of Research on Teaching**. New York Maemillan, 3-36.

______. 1986b. “Those Who Understand: Knowledge Growth in Teaching.” **Educational Researcher** 15 (2): 4-14.

______. 1987. “Knowledge and Teaching: Foundations of the New Reform.” **Harvard Educational Review** 57: 1–22.

Sinlarat, P. 1999. "Alternative Forms of In-service Training in the Redeployment of Teachers." **In Education Management and Financing in Thailand: Review and Recommendations Research Papers.** Bangkok: UNESCO

Siribanpitak, P. 2004. **Site-visits Monitoring Report on School-Based Training for In-service Teacher Development Project**. Bangkok: OEC.

Sternberg, R. J. 2002. "Raising the Achievement of all Students: Teaching for Successful Intelligence." **Educational Psychology Review** 14 (4): 383-393.

Tamir, P. 1998. "Assessment and Evaluation in Science Education: Opportunities to Learn and Outcomes." In B. J.Fraser and K. G. Tobin. (eds.). **International handbook of science education** Dordrecht: Kluwer, 716-789.

Thomas, J. A. 2003. "Reforming Elementary Science Teacher Preparation: What about Extant Teaching Beliefs." **School Science and Mathematics** 103 (7): 319-330.

Thousand, J. and R. Villa. 2000. "Collaborative teaming: A Powerful Tool in School Restructuring." In R.A. Villa and J.S. Thousand. **Restructuring for Caring and Effective Instruction: Piecing the Puzzle Together.** Baltimore: Paul H. Brookes Publishing Co, 254-293.

Tobin, K. and C. J. McRobbie. 1996. "Cultural Myths as Constraints to the Enacted Science Curriculum." **Science Education** 80: 223 - 241.

Tobin, K., Zurbano, R., A. Ford, and C. Carambo. 2003. "Learning to Teach through Coteaching and Cogenerative Dialogue." **Cybernetics and Human Knowing** 10 (2): 51–73.

Trundle, K. C., R. K. Atwood, and J. E. Christopher. 2007. "Fourth-Grade Elementary Students'Conceptions of Standards-Based Lunar Concept." **International Journal of Science Educatio**n 29 (5): 595–616.

van Driel, J. H., D. Beijaard, and N. Verloop. 2001. "Professional Development and reform in Science Education: The Role of Teachers' Practical Knowledge." **Journal of Research in Science Teaching** 38 (2): 137-158.

van Driel, J. H., N. Verloop, and W. De Vos. 1998. "Developing Science Teachers' Pedagogical Content Knowledge." **Journal of Research in Science Teachin**g 35: 673-695.

van Driel., O. De Jong, and N. Verloop. 2002. "The Development of Pre-service Chemistry teachers' Pedagogical Content Knowledge". **Science Education**, 86 (4): 572-590

Veal, W. R. 2004. "Belief and Knowledge in Chemistry Teacher Development." **International Journal of Science Educatio**n 26 (3): 329-351.

Verjousky, J. and G. Waldegg. 2005. "Analysizing Beliefs and Practices of a Mexican High School Biology Teacher." **Journal of research in Science Teaching** 42 (4): 465-491.

Verloop, N., J. van Driel, and P. Meijer. 2001. "Teacher Knowledge and the Knowledge base of Teaching." **International Journal of Educational Research** 35 (5): 441-461.

Villa, R., J. Thousand, and A. Nevin. 2008. **A Guide to Co-Teaching: Practical Tips for Facilitating Student Learning**. Thousand Oaks, CA: Corwin Press.

Vosniadou, S. 2001. Conceptual Change Research and the teaching of Science. In H. Behrendt, H. Dahncke, R. Duit, W. Gr¨aber, M. Komorek.

Wolcott, H. F. 1992. "Posturing in Qualitative Research." In M. LeCompte, W. Milroy and J. Prissle. (eds)." **Handbook of Qualitative Research in Education**, San Diego, CA: Academic Press, 3-52.

Yutakom, N. and P. Chero. 1999. **Reporting of In-service Science Teacher Professional Development in Accordance with the National Education Act of B.E. 2542**. Bangkok: IPST.

Zacharia Z. A., G. Olympiou, and M. Papaevripidou. 2009. "Effects of Experimenting with Physical and Virtual Manipulative on Students 'Conceptual Understanding in Heat and Temperature." **Journal of Research in Science Teaching** 45 (9): 1021–1035.

Zeidler, D. 2002. "Dancing with Maggots and Saints: Visions for Subject-Matter Knowledge, Pedagogical Knowledge and Pedagogical Content Knowledge in Science Teacher Education Reform." **Journal of Science Teacher Education** 13: 27–42.

Znaniecki, F. 1934. **The Method of Sociology**. New York: Farrar and Rinehart.

Zohar, A. 2004. "Elements of Teachers' Pedagogical Content Knowledge Regarding Instruction of Higher Order Thinking." **Journal of Sceicne Teacher Education** 15 (4): 293-312.

______. 2004a. **Higher Order Thinking in Science Classrooms: Students' Learning and Teachers' Professional Development**. Dordrecht, the Netherlands: Kluwer Academic.

______. 2004b. "Elements of Teachers' Pedagogical Knowledge Regarding Instruction of Higher Order Thinking." **Journal of Science Teacher Education**. 15 (4): 293–312.

APPENDICES

Appendix A

Reflective Protocol

Reflective Protocol for CTM I (Exploration Phase)

Written Reflection of Inquiry-Based Instruction
General Science Subject
Elementary Level
For Schools Participating in the CTM

Explanation

Please write or type a reflection on your classroom teaching of this lesson and then give this reflection to the researcher. In the reflection, please describe your practice (things you actually did in class), thoughts (things you think you should/shouldn’t do), and feeling according to the following questions:

1. General Information
    - Grade Level
    - Topic of Study
    - Number of Students (Male/Female)
    - Learning Objectives
2. What do you think or feel with your teaching in this lesson? Please provide evidences that support you thinking and feeling.
3. Do you think whether or not the students achieve learning goals or purposes in this lesson? Why do you believe that? Please explain.
4. What do you think or feel with your science knowledge when you implement your lesson? Why?
5. What are the things you did in this lesson that you think/feel appropriate for students in terms of their science learning? Why?
6. How did you know the students understand science?
7. Which parts of your practice are represented with inquiry-based teaching and learning? Please explain.

8. If you have a chance to teach this topic again, what will you do that are different from this lesson? How these differences help students in terms of their science learning?
9. What are the practices you did in this lesson that you want to keep for your future teachings? Why?
10. What are the practices you did in this lesson that you *do not* want to keep for your future teachings? Why?
11. What have you learned from this lesson in relation to inquiry-based instruction?
12. What are the problems or issues occurred in this lesson that you want to solve/ improve?

Yours sincerely,

………………………….

(Ms. Siriwan Chatmaneerungcharoen)
Ph.D. Candidate
The Program to Prepare Research and Development Personnel for Science Education
Department of Education, Faculty of Education, Kasetsart University

Reflective Protocol for CTM II-IV

(Co-planning, teaching and evaluating Phases)

Written Reflection of Inquiry-Based Instruction
General Science Subject
Elementary Level
For Schools Participating in the CTM

Explanation

Please write or type a reflection on your classroom teaching of this lesson and then give this reflection to the researcher. In the reflection, please describe your practice (things you actually did in class), thoughts (things you think you should/shouldn't do), and feeling according to the following questions:

1. General Information
    - Grade Level
    - Topic of Study
    - Number of Students (Male/Female)
    - Learning Objectives

2. Do you think your lesson related with the School-based Curriculum? How?
3. How did you develop your inquiry-based lesson?
4. Do you think whether or not the students achieve learning goals in this lesson? Why do you believe that? Please explain.
5. What do you think or feel with your science knowledge when you implement your lesson? Why?
6. What are the things you did in this lesson that you think/feel appropriate for students in terms of their science learning? Why?
7. How did you know the students understand science?
8. Which parts of your practice are represented with inquiry-based teaching and learning? Please explain.

9. Did you elicit students' prior knowledge in this lesson? If yes, how did you do?
10. What is/are the main questions students address in this lesson? Do you think this question is scientifically oriented question? Why?
11. Do you think students were interested in that main question? What did you do to motivate students' interest of the main question?
12. How did students formulate the main question? What was a scientific investigation that students use for answering the question?
13. Who was the one design the investigation? (Students, the teacher, or both) please explain.
14. Who was the one to analyze data gathered from the investigation and to formulate conclusion/explanation? How did you do?
15. Did you connect the conclusion/explanation with students' prior knowledge? If yes, how did you do?
16. Did you link the conclusion/explanation related science concept? If yes, how did you do?
17. Did you enhance the students connect their conclusion with their initial knowledge? How?
18. Did you have students learn in groups in this lesson? If yes, how did you group students? Why?
19. How did you group students into group work?
20. What do you think as your role in this inquiry-based lesson? Why do you believe that, please explain?
21. What do you think as student role in this lesson? Why do you believe that, please explain?
22. What are the things you did in this lesson that you think/feel appropriate for students in terms of their science learning? Why?
23. What are the things you did in this lesson that you think/feel *inappropriate* for students in terms of their science learning? Why?
24. What have you learned from this lesson in relation to inquiry-based instruction though CTM?

25. What are the problems or issues occurred in this lesson that you want to solve/ improve?

Yours sincerely,

………………………….
(Ms. Siriwan Chatmaneerungcharoen)
Ph.D. Candidate
The Program to Prepare Research and Development Personnel for Science Education
Department of Education, Faculty of Education, Kasetsart University

Appendix B

Semi-Structured Interview Protocol

Semi-structured Interview Protocol of Teacher's Understanding and Practice of Pedagogical Content Knowledge [PCK] before Participation in the CTM

(CTM I: Exploration Stage)

Teacher:……………………………………………………………………………….

School: ………………………………………………………………………………

Interviewer: …………………………………………………………………………

Date:…………………………………………Time:…………………………………

Interview Context: …………………………………………………………………

………………………………………………………………………………………..

………………………………………………………………………………………..

Part 1: Teacher's Background

1. Education
2. Science teaching experience (in elementary level)
3. Number of students in a classroom

Part 2: Teacher's Understanding and Practice of PCK

1. How do you teach science subject, in particular?
2. After the students learn science from you, what are the expectations that the students should get from your lesson?
3. How do you develop your lesson plan? (The Science Curriculum Framework or The School-based Curriculum)
4. Do you feel confident with your science knowledge when you are teaching? Why?
5. Do you use any school or community contexts integrated with your lesson plans? How?
6. Have you heard about inquiry approach?
7. What is inquiry-based instruction according to your understanding?
    - What is/are the teacher role in inquiry-based classroom?
    - What is/are the student role in inquiry-based classroom?
8. Have you ever taught science through inquiry?

- If yes, what are the reasons you decide to teach your lesson through inquiry?
    1. What kind of lesson/content that you believe suitable for inquiry teaching?
    2. Could you give an example of inquiry-based lesson that you used or have experienced? (Continue with item 4)
- If no, what are the reasons that you do not use this approach in your lessons?
- Could you think of any teachers or classes that taught via inquiry? What did the teacher or students did in that lesson? (Continue with item 4)

9. What the teacher did/should do for introduce the inquiry-based lesson?
10. What do students do to study the lesson?
11. Who was the one to design investigation students used in the lesson?
12. Which was the method students used for collecting data? How do students get the method?
13. How did students do to make conclusion?
14. Did students have a chance to share their conclusion with other? If yes, how did they present their conclusion?
15. Did students have a chance to work in group? If yes, how did they work in groups? What do you think about group work?
16. What do you view as benefits and limitations of inquiry-based instruction?
17. What do you want to change or improve in terms of your teaching through inquiry?
18. How do you know your students learn science through your teaching?
19. What is your expectation or hope to gain by engaging in this professional development program?
20. Do you have any questions or suggestions regarding this interview?

Semi-structured Interview Protocol of Teacher's Understanding and Practice of Pedagogical Content Knowledge [PCK] before Participation in the CTM

(CTM II: Preparation- CTM IV: Co-Teaching and Evaluating)

Teacher:…………………………………………………………………………………..
School: ……………………………………………………………………………………
Interviewer: ………………………………………………………………………………
Date:…………………………………………Time:…………………………………..

Interview Context: ………………………………………………………………………
………………………………………………………………………………………………..
………………………………………………………………………………………………..

1. What are the learning and teaching goals of this lesson?
2. Do you think students achieve the learning goals?
   - If yes, which are the goals they achieve? How do you know?
   - If no, which are the goals they don't achieve? How do you know?
3. What science topics did you co-teach with your co-teacher?
4. How did you feel with your science knowledge during co-teaching?
5. Did you elicit students' prior knowledge in this lesson?
   - If yes, what did you do?
   - If no, why didn't you do?
6. What is the main question (scientifically oriented question) that students address in this lesson? How do they get the question?
7. Do you think students are interested in this question?
   - If yes, how do you know? What did you do to motivate their interest?
   - If no, why don't you do?
8. What is the way/method students used for answering the question? How do students get that way/method?
9. How did students record and analyze the data? How do they get the way/technique for recording and analyzing data?
10. How did students make conclusion or formulate answer of the main question?

11. Did students have a chance to communicate their conclusion with the others?
    - If yes, how did they do?
    - If no, why don't you do
12. Did students have a chance to connect the conclusion with their prior knowledge?
    - If yes, how did they do?
    - If no, why don't you do
13. Did you introduce the related science concept to students, after completing investigation?
    - If yes, how did you do?
    - If no, why don't you do?
14. How do you have students work in groups in this lesson?
15. What do you believe as your role in this lesson?
16. What do you think as the student role in the lesson?
17. What are the things that you want to change or improve in relation to your teaching of inquiry-based instruction?
18. At present, do you think you have a better understanding of inquiry? Why? What do you know more, in short?
19. How did you know that the students learn science?
20. Do you have any questions or suggestions regarding this interview?

Appendix C

Schedule of Overall Meetings with Teachers

Appendix Table C1 Schedule of Overall Meetings with Teachers

M/D/Y	Participant	Activity	Time
CTM I: Exploration			
Jul. 02, 2009	Malai Napaporn Sirod	- First central meeting -Visit school/classroom - Explain the study plan - Set up shared goals	08.30-11.00
Jul.06, 2009	Malai Napaporn Sirod	- Visit school/classroom - Practice reflective writing - Card sorting#1	16.00-17.30
Jul. 08, 2009	Malai Napaporn Sirod	- Visit school/classroom - Practice reflective writing - Advise the teacher regarding the reflective writing	16.00-17.30
Jul. 28, 2009	Sirod	- Visit school/classroom - Classroom observation - Written reflection#1 - Interview#1	08.30-10.30
Jul 29,2009	Napaporn	- Classroom observation - Written reflection#1 - Interview#1	08.30-10.30
Jul 31,2009	Malai	- Classroom observation - Written reflection#1 - Interview#1	13.00-14.30
Aug.18, 2009	Sirod	- Visit school/classroom - Classroom observation - Written reflection#2 - Interview#2	08.30-10.30
Aug. 19,2009	Napaporn	- Classroom observation - Written reflection#2 - Interview#2	08.30-10.30

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
CTM1: Exploration (Continued)			
Aug. 20,2009	Malai	- Classroom observation - Written reflection#2 - Interview#2	13.00-14.30
Aug.25, 2009	Sirod	- Visit school/classroom - Classroom observation - Written reflection#3 - Interview#3	08.30-10.30
Aug. 26,2009	Napaporn	- Classroom observation - Written reflection#3 - Interview#3	08.30-10.30
Aug. 27,2009	Malai	- Classroom observation - Written reflection#3 - Interview#3	13.00-14.30
Sep.01, 2009	Sirod	- Visit school/classroom - Classroom observation - Written reflection#4 - Interview#4	08.30-10.30
Sep.02 ,2009	Napaporn	- Classroom observation - Written reflection#4 - Interview#4	08.30-10.30
Sep.03,2009	Malai	- Classroom observation - Written reflection#4 - Interview#4	13.00-14.30
CTM I1: Preparation			
Oct.18, 2009	Malai	- Workshop	9.30-15.00
Oct.19, 2009	Napaporn	-Written reflection #5-7	
Oct.20, 2009	Sirod	-	
Oct.21, 2009			
Oct.22, 2009			

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
CTM II: Preparation (Continue)			
Nov. 06, 2009	Malai	- Informal workshop	
Nov. 13, 2009	Napaporn	Written reflection #8	9.30-12.00
Nov.22, 2009	Sirod	- Interview #5	
Nov. 27, 2009	Malai Napaporn Sirod	- Second central meeting - Written reflection #9 - Card Sorting#2	9.30-12.00
CTM III : Co-Planning			
Nov. 28-Dec. 03	Individual teachers	Design the framework of inquiry-based lesson plans	6 days
Dec.04, 2009 Dec.11, 2009 Dec. 18, 2009 Dec. 25, 2009	Malai Napaporn Sirod	- Co-teacher work and assist other regarding lesson plan and instruction. Topics for consulting include concept begin focused, learning goals and purposes (scientific knowledge, science process skills, scientific attitudes), group work, formulation of conclusion, motivational activity, scientifically oriented question, scientific investigation, content knowledge, assessment and evaluation, communication of data, respect of other people' opinions, value students' answers, difficulty in teaching. - Microteaching - Written a reflection #10-13 - Interview #6-7	16.00-17.30

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
CTM III: Co-Planning (Continued)			
Dec. 27, 2009	Sirod	- Card sorting#3	10.30-11.30
Dec. 27, 2009	Malai	- Card sorting#3	12.30-13.30
Dec. 28, 2009	Malai	- Card sorting#3	10.30-11.30
CTM IV: Co-Teaching and Evaluating			
Jan.06, 2010	Napaporn	-Co-teaching with Sirod #1 -Co-evaluating among co-teachers and researcher -Classroom observation#5 -Written reflection#14	8.30-10.30 10.30-11.00
Jan.07, 2010	Malai	-Co-teaching with Napaporn #1 -Co-evaluating among co-teachers and researcher -Classroom observation#5 -Written reflection#14	8.30-10.30 10.30-11.00
Jan.13, 2009	Napaporn	-Co-teaching with Malai #2 -Co-evaluating among co-teachers and researcher -Classroom observation#6 -Written reflection#15	8.30-10.30 10.30-11.00
Jan.14, 2009	Malai	-Co-teaching with Sirod #2 -Co-evaluating among co-teachers and researcher -Classroom observation#6 -Written reflection#15	8.30-10.30 10.30-11.00
Jan.15, 2009	Sirod	-Co-teaching with Malai #1 -Co-evaluating among co-teachers and researcher -Classroom observation#5 -Written reflection#14	8.30-10.30 10.30-11.00

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
CTM IV: Co-Teaching and Evaluating			
Jan.22, 2009	Sirod	-Co-teaching with Napaporn #2 -Co-evaluating among co-teachers and researcher -Classroom observation#6 -Written reflection#15	8.30-10.30 10.30-11.00
Feb.03, 2010	Napaporn	-Co-teaching with Malai #3 -Co-evaluating among co-teachers and researcher -Classroom observation#7 -Written reflection#16	8.30-10.30 10.30-11.00
Feb.04, 2010	Malai	-Co-teaching with Napaporn #3 -Co-evaluating among co-teachers and researcher -Classroom observation#7 -Written reflection#16	8.30-10.30 10.30-11.00
Feb.10, 2009	Napaporn	-Co-teaching with Sirod #4 -Co-evaluating among co-teachers and researcher -Classroom observation#8 -Written reflection#17	8.30-10.30 10.30-11.00
Feb.11, 2010	Malai	-Co-teaching with Napaporn#4 -Co-evaluating among co-teachers and researcher -Classroom observation#8 -Written reflection#17	8.30-10.30 10.30-11.00
Feb.12, 2009	Sirod	-Co-teaching with Napaporn #3 -Co-evaluating among co-teachers and researcher -Classroom observation#7 -Written reflection#16	8.30-10.30 10.30-11.00

Appendix Table C1 (Continued)

M/D/Y	Participant	Activity	Time
CTM IV: Co-Teaching and Evaluating			
Feb.19, 2010	Sirod	-Co-teaching with Malai #4 -Co-evaluating among co-teachers and researcher -Classroom observation#8 -Written reflection#17	8.30-10.30 10.30-11.00
Feb. 22, 2010	CTM Team	-Forth Central Meeting -Evaluating on co-teaching for four inquiry-based lesson plans - Card Sorting#4	16.30-18.00
Feb. 27, 2010	CTM Team	-Fifth Central Meeting -Evaluating on CTM - Interview#8	9.30-12.00

Appendix D

Distribution of Activities and Data Collections of the Study

Appendix Table D1 Distribution of Activities and Data Collections of the Study

CTM I : Exploration

Purposes of Activities	**Activities**	**Data Collections**	**2009** Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	**2010** Jan.	Feb.
To set up a common goal for engaging in the CTM	First centre meeting	---								
To build up a confidential and familiarity relationship among the researcher, teachers, and students.	School/classroom visits Informal talks	---								
To practice teachers in written reflection.	Writing reflections	---								
To explore teachers' initial understanding and practice of PCK	Card Sorting Individual interview	Interview transcription								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data Collections	2009						2010	
				Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
CTM I (Continued)	To explore teachers' initial understanding and existing practice of PCK	Being observation, Reflecting on practice	Inquiry-based lesson plans, Videos of classroom instruction, Written reflection								
CTM II: Preparation	To encourage the teachers' awareness of the importance of PCK; to set up the essential features of IBI of this study; to provide the teachers with the chance to share their lesson plan, teaching experience, and difficulties in understanding and implementing inquiry-based lesson; to assist and support each other in improving inquiry-based lessons.	Second central meeting	Videos of the meeting								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data Collections	2009 Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	2010 Jan.	Feb.
CTM II: Preparation (Continued)	To learn PCK through reflection on their own instructions, communication with each other, and participation in activities designed by the researcher.	Second central meeting	Videos of the meeting								
CTM III: Co-Planning	To promote teacher's understanding and practice of PCK through a co-teaching model	Teacher planed an inquiry-based lesson plan	---								
		Teacher implemented the lesson in microteaching	---								
		CTM members assisted the teacher regarding lesson plan and instruction.	---								
		Teacher observed his instruction via video.	---								
		Teacher wrote a reflection on his teaching practice.	---								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data Collections	2009 Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	2010 Jan	Feb.
CTM III: Co-Planning (Continued)	To explore teacher's understanding of PCK.	Individual interview	Interview transcription								
	To explore teacher's understanding and practice of PCK.	Designing inquiry-based lesson plan, Being observation, Reflecting on practice	Inquiry-based lesson plan , Videos of classroom instruction, Written reflection								
	To provide the teachers with the opportunity to share their lesson plans, teaching experiences, and difficulties in understanding and implementing inquiry-based lesson; to assist and support each other in improving inquiry-based lessons.	Third central meeting	Videos of the meeting								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data Collections	2009 Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	2010 Jan.	Feb.
CTM II I (Continued)	To learn PCK through reflection on their own instructions and communication with each other, and participation in activities provided by the researcher.	Third central meeting	Videos of the meeting								
CTM IV: Co-Teaching and Evaluating	To promote teacher's understanding and practice of PCK by working through the Co-teaching and Evaluating.	Teacher revised an inquiry-based lesson plan	---								
		Co-teacher implemented the lesson in real classroom.	---								
		CTM members assisted the teacher regarding evaluate on lesson and practice	---								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data collections	2009 Jul.	Aug	Sep.	Oct.	Nov.	Dec.	2010 Jan	Feb
CTM IV: Co-Teaching and Evaluating	To explore teacher's understanding of PCK.	Individual interview Card Sorting	Interview transcription								
	To explore teacher's understanding and practice of PCK.	Designing inquiry-based lesson plan, Being observation, Reflecting on practice	Inquiry-based lesson plan, Videos of classroom instruction, Written reflection								
	To provide the teachers with the opportunity to share their lesson plans, teaching experiences, and difficulties in understanding and implement-ting inquiry-based lesson; to assist and support each other in improving inquiry-based lessons; to learn PCK through sharing and communicating with each other.	Forth central meeting	Videos of the meeting								

Appendix Table D1 (Continued)

	Purposes of Activities	Activities	Data collections	2009 Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	2009 Jan.	Feb.
CTM IV (Continued)	To provide the teachers with the opportunity to share, reflect, and discuss on CTM	Fifth central meeting	Videos of the meeting								

APPENDIX E:

Field Notes

Field Note

Teacher's name……………………………………………………………………………….

Subject…………………..**Topic**..**Class**………………………….

Date..................................**Time**……………..**The number of class period**………………

Physical environment

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Instructional Process

Lesson Introduction	Opinion
....	....

Investigation	Opinion
………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… …………………………………………………………………………	……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ………………………………………………
Conclusion	**Opinion**
………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… ………………………………………………………………………… …………………………………………………………………………	……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ……………………………………………… ………………………………………………

Note……………………………………………………………………………………..
…………………………………………………………………………………..………
……………………………………………………………………………………………..

APPENDIX F:

Co-Teaching Model Protocol

COMMON ISSUES AND PRACTICAL SOLUTIONS TO CO-TEACHING

Self Assessment: "Are We Really Co-Teachers?"

Teacher Name…………………………………………………………..

Date………………………………………………**Grade**……………

Directions: Respond to each question below to determine your co-teaching score at this point in time

1. Rarely **2. Sometimes** **3. Usually**

In our co-teaching partnership…

1.	We decide which co-teaching model we are going to use based on the benefits to students and co-teachers.	1	2	3
2.	We share ideas, information, and materials.	1	2	3
3.	We identify the resources and talents of the co-teachers.	1	2	3
4.	We teach different groups of students at the same time.	1	2	3
5.	We are aware of what our co-teacher (s) is doing even when We are not directly in his or her presence.	1	2	3
6.	We share responsibility for deciding what to teach.	1	2	3
7.	We agree on the curriculum standards that will be addressed in a lesson.	1	2	3
8.	We share responsibility for deciding how to teach.	1	2	3
9.	We share responsibility for deciding who teaches parts of t he lesson.	1	2	3
10.	We are flexible and make changes, as needed, during a lesson.	1	2	3
11.	We identify student strengths and need.	1	2	3
12.	We share responsibility for differentiating instruction.	1	2	3
13.	We include others when their expertise or experience is needed.	1	2	3

14.	We share responsibility for how student learning is assessed.	1	2	3
15.	We can show that students are learning when we co-teach.	1	2	3
16.	We agree on discipline procedures and implement them together.	1	2	3
17.	We provide feedback to each other on what goes on in the classroom.	1	2	3
18	We improve our lessons based on what happens in the classroom.	1	2	3
19.	We freely communicate our concerns.	1	2	3
20.	We have a process for resolving disagreements which we use When faced with challenges and conflicts.	1	2	3
21.	We celebrate the process, outcomes, and successes of co-teaching.	1	2	3
22.	We have fun with each other and the students when we co-teach.	1	2	3
23.	We have regularly scheduled times to meet and discuss our work.	1	2	3
24.	We use our meeting time productively.	1	2	3
25.	We effectively co-teach even without common planning time.	1	2	3
26.	We explain co-teaching benefits to students and their families.	1	2	3
27.	We model collaboration and teamwork for our students.	1	2	3
28.	We are both viewed by our students as their teacher.	1	2	3
29.	We include students in the co-teaching role.	1	2	3
30.	We depend on one another to follow through on responsibilities.	1	2	3
31.	We seek and enjoy additional training to improve our co-teaching.	1	2	3
32.	We are mentors to others who want to co-teach.	1	2	3
33.	We use various co-teaching models.	1	2	3
34.	We communicate our needs tour administrators.	1	2	3
35.	We respect and appreciate the contributions of our co-teacher.	1	2	3

Total co-teaching score: ______________________________

Information about Student Characteristics and Classroom Demands

Teacher Name…………………………………………………………………..

Date…………………………………………**Grade**……………………………

Student Characteristics	**Classroom Demands**
Student Characteristics Background Knowledge and Experiences Interests Learning Style(s) Multiple Intelligences Important Relationships Other: ____________ Other: ____________	Content Demands How the content is made available to the learners? What multi-level materials are used?
	Process Demands What processes or instructional methods do the co-teachers use to facilitate student learning?
Goals Does this learner have any unique goals related to academic learning, communication, English language acquisition, and/or social-emotional functioning? Are there particular concerns about this learner?	Product Demands How do the students demonstrate what they have learned? How are students assessed or graded?

BIOGRAPHICAL DATA

NAME – SURNAME	Miss Siriwan Chatmaneerungcharoen
DATE OF BIRTH	August 4th, 1982
PLACE OF BIRTH	Nakhonprathom, Thailand
EDUCATION	2005 B.S. (Biology) with Second Class Honors, Kasetsart University
	2006 Grad.Dip. (Teaching Science Profession) Kasetsart University
	2009 International Research Internship, University of British Columbia
SCHOLARSHIPS	2005 – 2011 Scholarships for studying in B.Sc., Grad. Dip. and Ph.D. from the Project for the Promotion of Science and Mathematics Talented Teachers (PMST), under the management of the Institute of Promotion of Science and Technology Teaching [IPST], Thailand.
	2009 The scholarships for research funding from the Graduate School, Kasetsart University, Thailand.